Hopi Arsenic Mitigation Project (HAMP)
10% Design Update Summary Report
IHS Project Number PH 18-V31

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MAY 2019

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Background and Introduction

Eight (8) public water systems (PWS) in the First and Second Mesa areas of the Hopi Reservation do not comply, or struggle to comply, with the federal Safe Drinking Water Act (SDWA) maximum contaminant level (MCL) of 10 parts-per-billion (ppb) arsenic (As) in the product of their community water systems. For those PWSs, naturally occurring levels of As in existing water supply source wells range from 12 – 35 ppb. Four village water systems are currently in violation of the 10 ppb As MCL. One tribal PWS, a Bureau of Indian Affairs (BIA) PWS and two (2) Bureau of Indian Education (BIE) PWSs are able to comply intermittently with the As MCL by utilizing a variety of difficult and expensive to operate As-removal treatment systems.

The 2014 HAMP Preliminary Engineering Report (PER)

In August of 2014 the Indian Health Service/Eastern Arizona District Office (IHS/EADO) published a Preliminary Engineering Report (PER) entitled: PRELIMINARY ENGINEERING REPORT FOR HOPI ARSENIC MITIGATION ALTERNATIVES, IHS Projects PH12-E73, PH11-E55, PH10-E37, PH08-T38, PH06-D33, PH04-S63.

The 2014 PER recommended that two (2) large-diameter, 2200-feet deep N-aquifer wells should serve as the dual-source for a regional water transmission system that would provide potable, SDWA-compliant water to the First and Second Mesa Hopi villages. Those wells, Turquoise Trail wells no. 2 and 3, were drilled in 2013 specifically for the purpose of serving the HAMP.

An old, smaller well that was previously drilled further north to provide construction water for the Tawa'ovi community development site is known as Turquoise Trail well no. 1. That well is not suitable as a HAMP water source.

The proposed 2014 PER system was to be configured as an "Inverted-Y" with the source wells at the (top) base of the wye while the two arms of the wye supplied water to the FMCV and Second Mesa village utilities respectively. The project would include multiple water storage tanks (WST), two (2) pressure-boosting stations and several pressure reducing valve (PRV) vaults for water which would descend from Upper Sipaulovi/Mishongnovi down to Lower Sipaulovi/Mishongnovi.

The "Inverted-Y" layout had initially been reviewed and approved by the Hopi Tribal Council in 2012, and then again in greater detail with publication of the 2014 HAMP PER. In August of 2014, un-funded cost estimates for the "Inverted-Y" system ranged from \$16M – \$18M.

Since the 25 April 2018 Hopi Tribal Council meeting, the IHS/EADO engineering staff, in consultation with HUC and Hopi HAMP village personnel, had further scrutinized the proposed 2014 PER "Inverted-Y" HAMP layout from a hydraulic, economic, constructability and cultural compatibility perspective. That scrutiny revealed construction and operational pumping cost concerns that could be mitigated through the consideration of alternative pipeline routing designs.

Project Funding

The main purpose of the August 2014 HAMP PER was to serve as justification for a project funding request to the United States Department of Agriculture–Rural Development (USDA-RD) program. If successful, that request would have provided 75% of remaining un-funded HAMP capital costs as a direct grant to the Hopi Tribe and a 40-year low-interest loan to the tribe as financing for the remaining 25% of un-funded project costs. The need to repay a 25% loan over a 40-year period was not a preferred option among residents of the First and Second Mesa Hopi villages which would be participating in the HAMP water supply effort and who, as the local water consumers and utility ratepayers, would become the back-bone of the HAMP utility operations financial support effort.

Between 2014 and 2018, the Hopi Tribe sought to address compliance with USDA-RD financial audit standards that would allow the tribe to submit a grant/loan application to that agency. In June 2017, the Hopi Utility Corporation (HUC) was chartered by the Hopi Tribe with the intent that the HUC would formally pursue a USDA-RD grant/loan as an independent entity of the Hopi Tribe. In addition, it was stated that the HUC would be the operator of all HAMP-system infrastructure which was not a part of existing village utility infrastructure.

During that time, multiple meetings between the USDA-RD, the Hopi Tribe, the HUC, the United States Environmental Protection Agency (USEPA) and the IHS/EADO occurred. During those meetings, the USDA-RD expressed its support for village based As-removal treatment plants as opposed to a regional distribution system without the need for treatment. i.e. the HAMP concept, as was preferred by the Hopi Tribe, the USEPA and the IHS.

In June of 2017 an expansive written response to the IHS/EADO August 2014 PER document was received by the IHS/EADO from the USDA-RD. That response strongly implied that the USDA-RD would only be willing to provide HAMP funding if a project design shift would be made toward the USDA-RD preference for construction and operation of multiple As-removal water treatment plants in the First and Second Mesa villages. Prior to the USDA-RD response, the Hopi Tribal Chairman and the affected First and Second Mesa villages had officially stated their strongly-held preference for a regional water transmission/distribution system option, i.e. the HAMP which utilizes Turquoise Trail Wells source water without a need for As-removal treatment facilities to be operated by the First and Second Mesa village utility organizations.

While attending a Hopi Tribal Council meeting on 25 April 2018, the IHS announced an allocation of $10M for the HAMP construction effort during FY 2018. At that time it was also announced that the USEPA would fund an additional $3M. The IHS FY2018 allocation was subsequently increased from $10M to $11M. Current and future HAMP project funding is delineated in Project Summary PH 18-V31 which was signed on August 29, 2018.The signing of the Project PH 18-V31 Memorandum of Agreement by the Hopi Tribal Council was completed in January, 2019. Project Summary PH 18-V31 denotes the projected availability of an additional $4M in IHS and EPA funds that presumably would be distributed over a 2-3 year period if future agency budgets allow.

When coupled with approximately $1.1M committed by the Hopi Tribe (through the HUC) for an electrical power main extension to the Turquoise Trail wells, the IHS and EPA funding commitments as are captured in Project Summary PH 18-V31 would meet the projected funding needs of the HAMP. The Hopi Tribe (through the HUC) has committed that if the power extension to Well No. 3 exceeds the $1.1M, the increase in cost will also be covered by the Tribe.

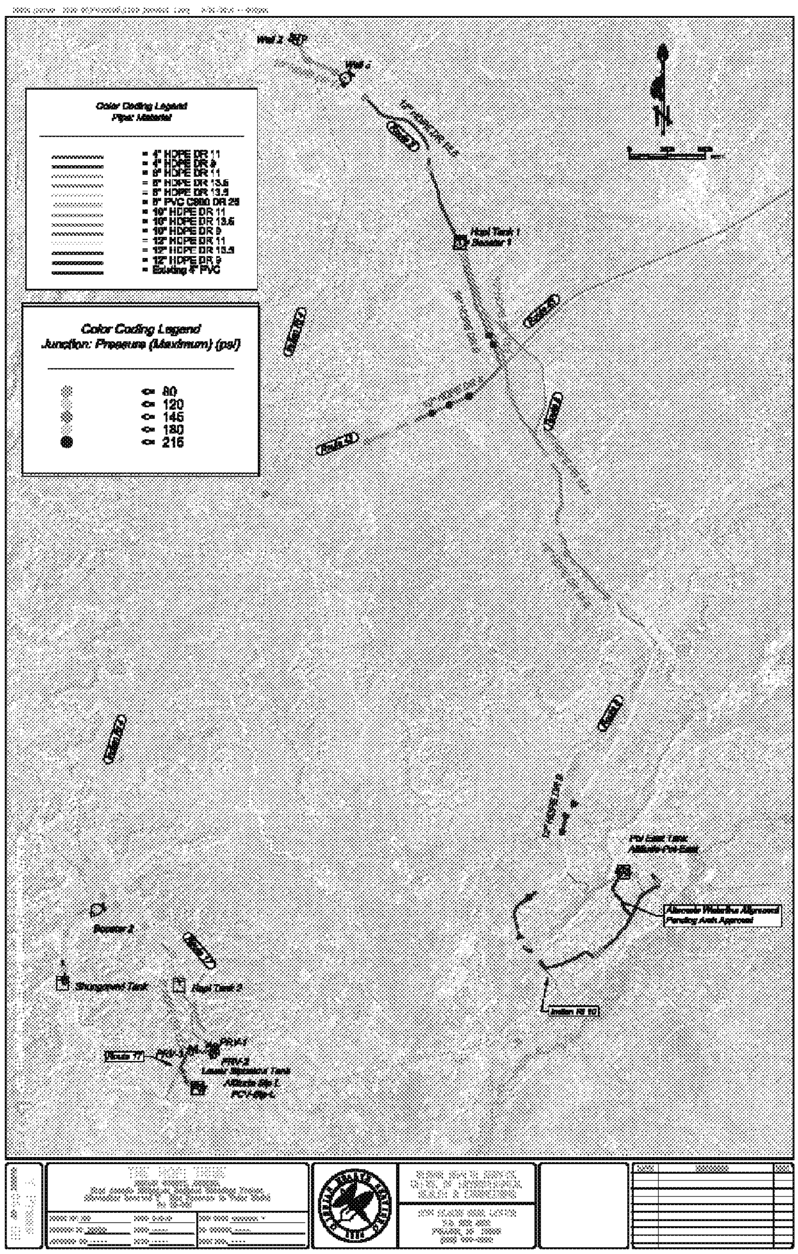
Design Options Introduction

The included design alignment options are a result of several factors. The amount of funding available as well as other considerations created a need to explore ways to decrease the cost of the 2014 PER alternative. As the 2014 PER alternative was refined from a preliminary design, improvements were discovered that would both save on energy costs as well as capitol cost. The following describes some of the aspects of the 2014 PER that were revealed to ~~be~~ opportunities for improvement and other considerations leading to a modified 2019 "Inverted Y" alternative. In addition to the "Inverted Y," other alignment alternatives are included that were analyzed in detail. Each of the three alternatives presented provide a path to transport water from the Turquoise Trail Wells to First and Second Mesas.

There are several reasons for re-evaluating the 2014 PER design. First, a decision was made to not install the pipeline over the mesa top of 1st Mesa. This decision was supported by IHS, the First Mesa Consolidated Villages, and the HUC. This decision reduced the amount of head needed to provide water to 1st Mesa by about 140 ft. Reducing the pumping head by 140 ft results in reducing pipe pressure class along much of the pipe route as well as reducing the yearly pumping energy costs. Another consideration was adding the cost of a powerline to the Radio Tower Tank Site and Radio Tower Booster Station shown in the 2014 PER. The PER assumed that an APS powerline would come from 2nd Mesa and pass by the Radio Tower site. The Hopi Tribe has since requested the powerline service to be provided by NTUA from the Hardrock Chapter area. That decision reduced the advantage of the Radio Tower site. The 2014 PER proposed an inline booster station to pump water to the Radio Tower Tank. An additional tank between the wells would have been considered to add some operational advantages over the inline booster system. Under the PER alternative, essentially all of the water for both 1st and 2nd mesa was being pumped to an elevation of 6300'. If the Radio Tank was moved to the Cultural Center closer to where power is at, then it would be pumping to about 6345'. Friction losses add to the pressure downstream of the booster station near the wells. The high pressure pipe for HDPE reduces the inside diameter. All the pipe to the 1st Mesa/2nd Mesa split would have needed to be 14" because of this. The pipeline to First Mesa from the split would have been a higher pressure class as well. The pipeline size and pressure class increase significantly increased the cost of the 2014 PER above initial estimates. All of these considerations lead to an alternative 2019 "Inverted Y" option.

Alternative Descriptions

The 2019 “Inverted Y” alignment was re-evaluated with the desired outcome to follow the 2014 PER alignment route as closely as possible. Several iterations of tank sizing locations, pipe sizing, and booster station locations were explored to arrive at the presented alternative. The 2019 Inverted Y would pump water from Turquoise Trail Well Nos. 2 and 3 to Hopi WST No. 1 adjacent to Route 8. From Hopi WST No. 1, water would flow by gravity through a transmission main to supply the FMCV/Polacca system East tank. By providing all of the FMCV supply to the East Tank, the parallel PRVs between the two FMCV pressure zones could be valved off with normally closed valves. The water would then flow through the upper pressure zone and through an altitude valve to the FMCV West tank which supplies the lower pressure zone. This would be the same for all three alternatives.

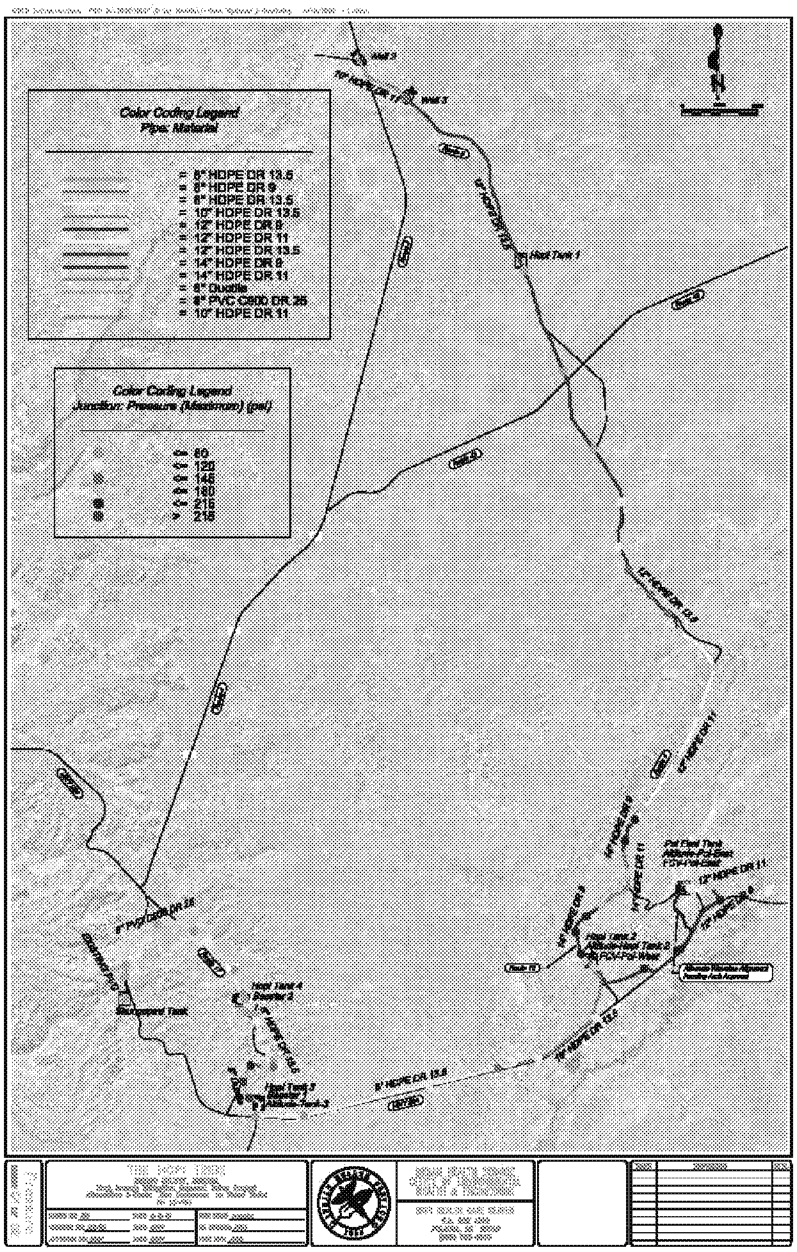


A booster station would also be located at WST No. 1 that would pump water to the Upper Sipaulovi Tank (WST No. 2). A power extension will need to be made from Well No. 3 to WST No. 1. There would be two water lines parallel to each other between WST No. 1 and the split. One line would continue south along Route 8 and the other would head southwest along route 43 toward Second Mesa.

WST No. 2 would provide storage for multiple purposes. First, it provides gravity storage to the Upper Sipaulovi System. It also provides storage for the Lower Sipaulovi System. When the Lower Sipaulovi existing water storage tank calls for water, it will be delivered from WST. No. 2. An altitude valve with flow control will be installed at the Lower Sipaulovi tank to control the flow of water from the HAMP line coming from the upper Second Mesa area. There will need to be three pressure reducing valves (PRVs) to drop the pressure as the water travels from upper Second Mesa to the Lower Sipaulovi system. WST No. 2 will also provide storage for a booster station that would be located on the dirt road south of the Cultural Center that connects HWY 264 and Route 17.

The booster station will pump water to the Shungopavi Water system with enough head to fill the elevated storage tank. The booster station will be controlled by radio from the Shungopavi elevated tank based on the water level in the tank. The HAMP line would end at the booster station with a water meter with the line between the booster station and the Shungopavi system becoming part of the Shungopavi system. There are several unserved homes along the HAMP transmission route near the cultural center along Route 17, Route 4, and Hwy 264 that could be served directly off of the HAMP line. Those homes would be customers of the HUC. Alternatively, a line could be extended from the Shungopavi water system to serve those customers. The Cultural Center would be served by HUC as well unless the extension from the Shungopavi water system is preferred and installed.

A Second alternative, the "J-hook" plan resembles a leftward facing hook that is initially aligned SSE along Route 8 from the Turquoise Trail wells to the west side of First Mesa from where it then arcs WSW along Hwy AZ 264 to Lower Sipaulovi/Mishongnovi before curving sharply northward through a booster station to Toreva and the top of Second Mesa where it would supply water to Upper Sipaulovi/Mishongnovi and all of Shungopovi.



The "J-hook" would pump water directly from Turquoise Trail Well Nos. 2 and 3 to Hopi WST No.1 adjacent to Route 8. From Hopi WST No.1, water would flow by gravity through a transmission main to supply the FMCV/Polacca system. Water would flow by gravity around the west side of First Mesa to the FMCV East WST. Water from the FMCV East WST would then pressurize and supply the four (4) existing pressure zones of the FMCV/Polacca distribution system just as it currently does. Through that process, the FMCV West WST would also be filled. Water from Hopi WST No. 1 would also flow to a new Hopi WST No. 2 that would be constructed adjacent to the existing FMCV West WST which will soon be replaced under IHS Project No. PH 15-U76. The transmission main would then extend WSW along Hwy AZ 264 to Lower Sipaulovi/Mishongnovi where it would fill the existing Lower Sipaulovi/Mishongnovi WST and a new Hopi WST No. 3. That new WST would be constructed adjacent to the existing Sipaulovi WST.

The new WSTs of the "J-hook" layout would provide additional storage and system redundancy. In addition, the new Hopi WST No. 3 in Sipaulovi would serve as the "positive-head" for a pressure boosting system which would be constructed next to that WST to pump water up through Toreva to Upper Sipaulovi/Mishongnovi and to WST No. 4 in the Upper Sipaulovi/Mishongnovi area. WST No. 4 will provide gravity storage to the Upper Sipaulovi water system. A second booster station located adjacent to WST No. 4 would provide water to the Shungopavi village water distribution system with enough head to fill the existing elevated WST.

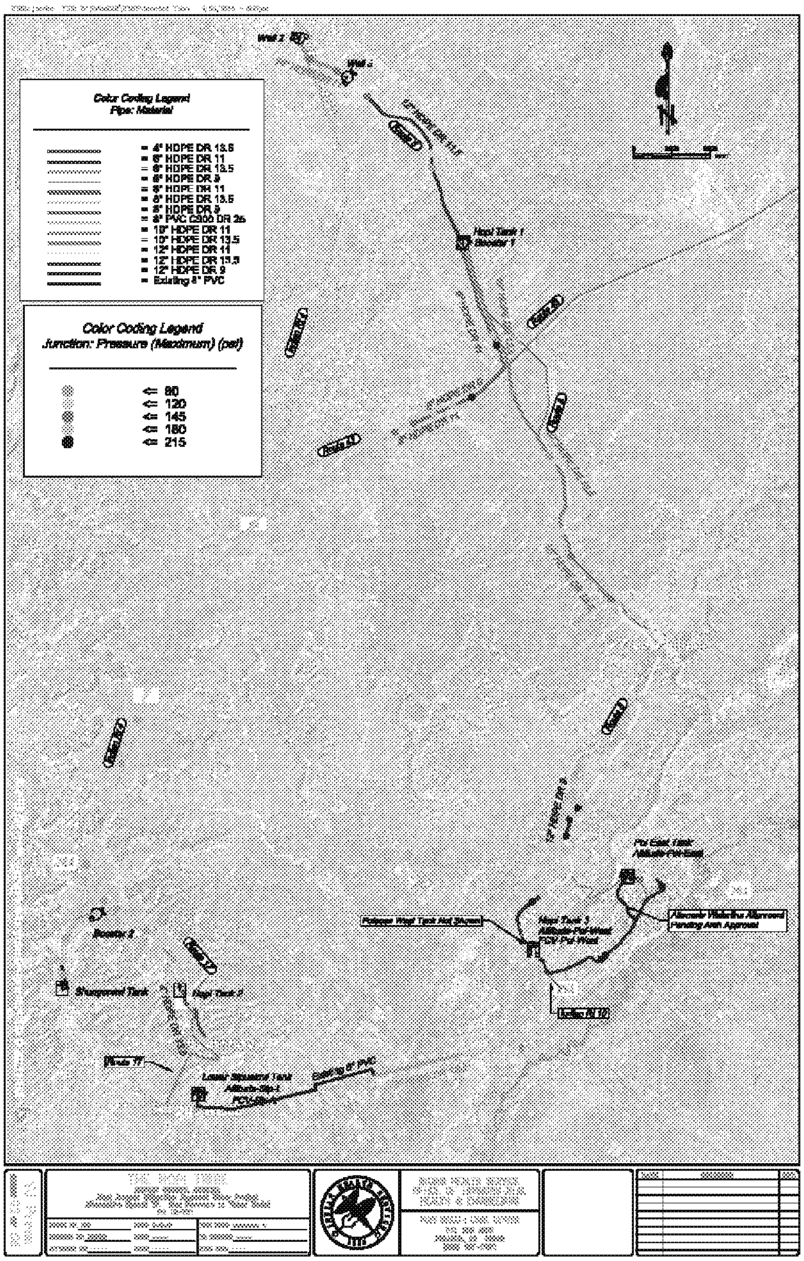
The HAMP transmission line would likely end at the booster station No. 2 adjacent to WST No. 4. Any homes north of the booster station would be served by the Shungopavi water system. The water line installed between booster station 2 and Shungopavi would become part of the Shungopavi water system.

The third alternative, the "Hybrid" is a varied version of the "Inverted Y". In a similar manner to the "Inverted Y", the "Hybrid" would pump water from Turquoise Trail Well Nos. 2 and 3 to Hopi WST No. 1 adjacent to Route 8. From Hopi WST No. 1, water would flow by gravity through a transmission main to pressurize and supply the FMCV/Polacca system. Water would flow around the west side of First Mesa to the FMCV East WST. Water from the FMCV East WST would then pressurize and supply the four (4) existing pressure zones of the FMCV/Polacca distribution system just as it currently does. Through that process, the FMCV West WST would also be filled. Water from Hopi WST No. 1 would also flow to a new Hopi WST No. 3 that would be constructed adjacent to the existing FMCV West WST which will soon be replaced under IHS Project No. PH 15-U76. The transmission main would then extend WSW along Hwy AZ 264, connecting to the east end of the Lower Sipaulovi/Mishongnovi system. A solenoid valve would be installed at the connection point which would be controlled with radio from the Lower Sipaulovi Tank. The valve would open and close based on the Lower Sipaulovi tank water level. Lower Sipaulovi tank would be a floating tank on the lower system. The HAMP line would end at the solenoid valve and a meter would also be installed adjacent to the valve.

A booster station would also be located at Hopi Tank 1 that would pump water to the Upper Sipaulovi Tank (WST No. 2). There would be two water lines parallel to each other between WST No. 1 and the split. One line would continue south along Route 8 and the other would head southwest along Route 43 toward Second Mesa.

WST No. 2 would provide storage for dual purposes. First, it provides gravity storage to the Upper Sipaulovi System. Additionally, WST No. 2 will provide storage for a booster station that would be located on the dirt road south of the Cultural Center that connects HWY 264 and Route 17.

The booster station will pump water to the Shungopavi Water system with enough head to fill the elevated storage tank. The booster station will be controlled by radio from the Shungopavi elevated tank based on the water level in the tank. The HAMP line would end at the booster station with a water meter with the line between the booster station and the Shungopavi system becoming part of the Shungopavi system. There are several unserved homes along the HAMP transmission route near the cultural center along Route 17, Route 4, and Hwy 264 that could be served directly off of the HAMP line. Those homes would be customers of the HUC. Alternatively, a line could be extended from the Shungopavi water system to serve those customers. The Cultural Center would be served by HUC as well unless the extension from the Shungopavi water system is preferred and installed.



One alternative within the "Hybrid" would be to install WST No. 2 at the Cultural Center instead of at the high point between the Cultural Center and Upper Sipaulovi. As a result of the tank moving, two booster stations would be located adjacent to WST No. 2. One booster station would pump to the Shungopavi water system. The other booster station would pump water to the Upper Sipaulovi water system. The second booster station would also be run with VFD drives to ramp up and down to maintain pressure in the system. A meter would be located at the outlet of each booster station which would be the transition points from HUC system to village systems.

There are some advantages and disadvantages to moving the tank to the Cultural Center. The advantages of moving the tank would be first, the tank at the Cultural Center could be shorter than at the high point. WST No. 2 would be 55 feet tall at the high point above Peach Lane and would only need to be 16 feet tall at the Cultural Center. The taller tank poses more risk with operations with an increased fall height hazard. The other advantage is that the HAMP line that would be operated by the HUC would end after the dual booster stations at the Cultural Center. This would simplify operation for HUC, but would have some disadvantages as well.

The first disadvantage of moving the water storage tank to the Cultural Center is that there is an increased capital cost. The increase in cost comes from increased road crossings, 1,700 feet of additional pipe, and an additional booster station. The estimated cost associated with these items is about $150,000 ($50,000 for the extra pipe length, $25,000 for the additional booster skid, and $40,000 for the road crossings plus TERO, Admin, contingency, Technical Support, etc.). Another disadvantage of moving the tank is that the Upper Sipaulovi water system will not have gravity water storage. If the booster skid becomes inoperable, the water system will be out of water within minutes. This could happen from power outages, control component failures, pump failures, etc. Gravity storage is the preferred method of providing water pressure and supply to a water system when economically feasible. The upper Sipaulovi system would be totally reliant on the booster pumps with the tank at the Cultural Center. The tank at the high point will provide a few days of backup storage in the case of a pump failure at Booster No. 1 near WST No. 1.

It is recommended that WST No. 2 be placed at the high point as shown on each of the alternative maps. The tank at the high point provides back up storage to the residents of the Upper Sipaulovi and Mishongnovi Villages while having the tank at the Cultural Center would only benefit the HUC as is simplifies the metering of water to the villages.

Assumptions, Observations and Constraints

A comparison of the HAMP system layout options reveals the following list of design observations and pros and cons.

1. Regardless of the pipeline design layout selection, the previously referenced $1.1M funding commitment from the Hopi Tribe/HUC for the extension of NTUA electrical power to the Turquoise Trail wells is a critical component of the overall HAMP funding scenario. Without a functional water source, i.e. power having been extended to the Turquoise Trail Wells, pipeline hydraulic pressure-testing and WST leak-testing will not be possible during the project construction phase. Thus, the Turquoise Trail wells must be energized and functional before pipelines and WSTs can be constructed and verified for their integrity. A generator could be used during construction, but having the power available provides more flexibility.
2. The 2014 PER “Alternative A” design is not being evaluated due to the changes required. The updated 2019 “Inverted Y” is being compared in place of the 2014 PER version.
3. The IHS/EADO construction cost estimate for the 2019 “Inverted-Y” design (exclusive of the well-power extension costs) is approximately $20.61M.
4. The estimated additional capital construction cost differential between the “Inverted-Y” layout with respect to committed project funding is approximately $1.61M. That differential has not been identified to be met with future IHS or USEPA funding. For the “Inverted-Y” layout to be selected/designated for construction as the HAMP solution, the Hopi Tribe would need to identify and appropriate the listed un-funded project capital cost amount.
5. The estimated construction cost for the “J-hook” design (exclusive of the well-power extension costs) is approximately $19.0M.
6. There is no estimated cost differential between the “J-hook” layout with respect to identified available project funding.
7. The IHS/EADO construction cost estimate for the 2019 “Hybrid” design (exclusive of the well-power extension costs) is approximately $20.5M.
8. The estimated additional capital construction cost differential between the “Hybrid” layout with respect to committed project funding is approximately $1.5M. That differential has not been identified to be met with future IHS or USEPA funding. For the “Hybrid” layout to be

selected/designated for construction as the HAMP solution, the Hopi Tribe would need to identify and appropriate the listed un-funded project capital cost amount.

9. In contrast to the 2014 PER "Inverted-Y" concept, the "J-hook", the 2019 "Inverted-Y" and the "Hybrid" system layouts both represent appreciable electrical pumping cost savings of at least $19,000/year beginning with system start-up. Such savings are possible because only the water which is used by the utility systems on Upper-Second Mesa, about 30% of total HAMP well production, will need to be pumped up to those higher elevations. Those savings are likely to increase over time as community water demands and the cost of power ($/kW) increase into the future.

10. The "J-hook" and "Hybrid" systems both eliminate the need for a series of pressure reducing valves (PRV) between Upper and Lower Sipaulovi/Mishongnovi. PRVs are known to be high maintenance installations which are critical to long-term system operational stability. The failure of a PRV could produce downstream main line breaks and potentially dangerous pressures at lower elevations. The elimination of PRV's further simplifies the operation of the regional water system and reduces life cycle costs.

11. By eliminating the need for PRV installations, the "J-hook" system will instead utilize a pressure booster station to pump water up to the Second Mesa villages from Lower Sipaulovi. That pump facility would operate up to 273-psi and the system piping between Upper and Lower Sipaulovi would be holding high pressures at the lower elevations of that hydraulic zone.

12. In contrast to the "J-hook" and "Inverted Y" designs, the "Hybrid" layout eliminates the need to construct through the Toreva area. This eliminated the need for PRVs through Toreva. Toreva is the area with the highest construction risk and several hundred feet of the water main will need to be constructed within existing paved roadway in the "J-hook" and "inverted Y" alignments through Toreva. There are also large blocks of rock along the route who's stability can be affected be excavation in the vicinity.

13. The "J-hook" design provides operational redundancy and facilitates O&M by siting two (2) HAMP-system WSTs where they can be manually backed-up by existing village WSTs. One of those WSTs would be next to the FMCV West WST and the other would be next to the Lower Sipaulovi/Mishongnovi WST. The "Hybrid" design provides one back-up WST next to the FMCV West WST. The "inverted Y" does not provide any WST next to existing WSTs.

14. Each of the three alternatives do not allow water to enter a village utility piping system and then transfer later to the distribution system of another village utility except in emergency. Thus, all water from the Turquoise Trail HAMP wells will remain in HAMP transmission pipelines until it is automatically transferred directly into village utility WSTs from which it cannot flow back into the HAMP piping network. This configuration allows the HUC to serve as a direct wholesale water provider. The USEPA-R9 could subsequently be classified each of the HAMP village PWSs as "consecutive" to the HUC/HAMP public water system, but not to each other.

15. Each of the three layout options provide full capacity to meet estimated 40-year water-system demands. Several key design modifications will need to be specified if the previously referenced BIA and BIE facilities elect to become customers of the HUC by direct connections to the HAMP system as proposed. Those modifications include increasing the system hydraulic capacity with the addition of an additional source well, additional storage to serve as a transmission main supply buffer and larger transmission piping in several key areas between the Turquoise Trail Wells and the FMCV.

16. In contrast to the "Inverted-Y" and "Hybrid", the "J-hook" system-layout would eliminate approximately 45,000-feet of pipeline that would otherwise need to be installed in "sandstone" which is known to be expensive on a "per-foot" basis when contrasted with excavation in less consolidated strata/soils. It is also likely that several more months of construction time would be required for that more difficult pipeline installation. The cost associated with the sandstone installation has been accounted for in the cost estimates.

Summary Table of Approximate Estimated Layout Option Construction Costs

System Layout Option	Estimated Approximate 2018 Capital Cost	Estimated Approximate Un-Funded Capital Cost
2019 Inverted-Y	$20.61M	$1.61M
Inverted-V	$20.5M	$1.5M
J-Hook	$19.0M	$0

Review of the 2014 PER recommended alternative and Modified Alternatives

The 2014 Preliminary Engineering Report had evaluated two (2) alternatives for providing SDWA arsenic compliant water to the First and Second Mesa Hopi villages. One of those alternatives was to continue utilizing the existing village water supply wells by constructing individual arsenic treatment facilities for each of the four (4) public water systems. In order to remove arsenic from the water which the supply wells in those villages produce, that option would have required the construction of two (2) treatment facilities in the FMCV (Polacca), one in Shungopavi, and one each in Upper Sipaulovi/Mishongnovi and Lower Sipaulovi/Mishongnovi. Treatment plants of the type which would have been required are expensive to operate and maintain in order to assure the provision of SDWA arsenic compliant water. Ultimately, and due to technical complexity as well as high O&M costs, a reliance on arsenic treatment systems was not preferred by the Hopi villages, the Hopi Tribe, the USEPA or the IHS. The 2014 PER did not endorse well-head treatment facilities as a preferred means of achieving arsenic compliance.

Instead, the 2014 PER recommended that a regional water system should be constructed to utilize the arsenic compliant water that is available to be pumped from the two (2) Turquoise Trail groundwater wells which had recently been drilled by the USEPA and the IHS. The 2014 PER proposed that, once funded, the "Inverted-Y" pipeline route should be designed in complete and final detail to serve as the skeletal backbone of a regional water transmission and supply system. The "Inverted-Y" route had originally been referenced as "Revised Alternative A" and was presented to the Hopi Tribal Council as one of three (3) pipeline route alternatives during the early stages of PER development in 2011-12. Evaluations and scoring for those three pipeline alignment alternatives (Alternatives A, B and C) are available for review in the environmental assessment (EA) document entitled Hopi Arsenic Mitigation Project – HAMP, Hopi Reservation, Navajo County, Arizona, Environmental Assessment, June 2014.

Although it was previously endorsed by the Hopi Tribal Council, the August 2014 HAMP PER "Alternative-A" system layout will require modifications to the original design and is being evaluated in this report as the 2019 "inverted Y". The "J-hook" is the only alternative which does not require additional construction funding beyond what has already been identified with a funding path by the IHS and the USEPA. The third alternative explored in this report is known as the "Hybrid" system. In order to proceed with tangible HAMP engineering design efforts so that

USEPA-R9 compliance deadlines can be met, the IHS supports the Tribe selecting one of the three engineering designs. IHS will support the Tribe's decision and work with the Tribe in securing additional funding. Possible funding sources for additional funding are USDA-RD, EPA, IHS, BOR, the Tribe, loans, or other sources. The IHS engineers have developed a hydraulic analysis of the three alternatives and the results of that analysis are referenced in this report and available for review.

Three (3) HAMP pipeline layout alternatives have been described in this report, the 2019 "inverted-Y," the "J-Hook," and the "Hybrid". Schematics for each of the alternatives are found in Appendix B.

As designed, the "Inverted-Y" alternative would install approximately 206,000 feet of potable water pipelines between the Turquoise Trail wells and the First and Second Mesa Hopi Villages. In addition to keeping all of the existing village-owned water system infrastructure in service, the "Inverted-Y" design includes the installation of well pumps in each of the Turquoise Trail Wells, the construction of two (2) new booster stations and the erection of two (2) new WSTs.

As designed, the "J-hook" alternative would install approximately 171,000 feet of potable water pipelines between the Turquoise Trail wells and the First and Second Mesa Hopi Villages. In addition to keeping all of the existing village-owned water system infrastructure in service, the "J-hook" design includes the installation of well pumps in each of the Turquoise Trail Wells, the construction of two (2) new booster stations and the erection of four (4) new WSTs.

As designed, the "Hybrid" alternative would install approximately 218,000 feet of potable water pipelines between the Turquoise Trail wells and the First and Second Mesa Hopi Villages. In addition to keeping all of the existing village-owned water system infrastructure in service, the "Hybrid" design includes the installation of well pumps in each of the Turquoise Trail Wells, the construction of two (2) new booster stations and the erection of three (3) new WSTs.

Each of the alternative system plans could utilize HDPE or PVC as its primary pipeline material. However, the long service-life of extended-length HDPE water transmission mains with a minimal number of pipe-joints is favored by the IHS and HUC for the HAMP-system. Areas that may be tapped by customers or turned over to village water systems will consider PVC. Ductile Iron Pipe will also be considered in the highest pressure areas.

For both cultural and technical reasons, a decision was also made to avoid the installation of HAMP transmission main piping over First Mesa within the roadway through the "gap". From the "gap" to the FMCV East WST, extensive cutting of existing road-asphalt would have been necessary to safely install a pipeline within that narrow road-prism corridor. This decision was supported by IHS, the First Mesa Consolidated Villages, its cultural leaders, and the HUC. By avoiding the "gap" area of the First Mesa, the amount of pumping elevation-head which would be needed to provide water to the FMCV system can be reduced by approximately 140-feet.

Under the 2014 HAMP PER "Inverted-Y" alternative, all of the water for the First and Second Mesa villages would have been pumped to an elevation of 6340-feet plus overcome additional friction losses where a WST was to be constructed near the Cultural Center on Route 4. However, under the three layouts in this report, all water must only be pumped to an elevation of 6166-feet in order to supply the FMCV system by gravity-flow. Thus, a new Hopi WST No. 1 would be constructed between the Turquoise Trail Wells and the FMCV system at a high point along the route that provides the 6166-foot high water overflow elevation. Approximately 74% of projected HAMP system water will be utilized by the FMCV. Thus, and by avoiding a need to pump all of the HAMP water higher than necessary, a significant reduction in pumping energy costs can be realized by all three of the presented alternatives

Comparative evaluations were conducted between the 2019 "Inverted-Y," the "J-hook," and "Hybrid" system layout options to evaluate initial capital cost, pumping energy cost, overall life cycle cost, capital replacement and rehab cost, ease of operation, impact to the NEPA schedule, constructability risk, and system-service redundancy.

Each of the four water systems that the HUC will provide water to with the completion of the HAMP will be considered consecutive water systems.

Methodology

Topographic information for the HAMP regional water system hydraulic analysis was gathered using Trimble R8 survey equipment. Fast static basepoints for the Hopi Reservation had been previously established by a professional surveyor and RTK data collection methods were utilized by IHS Polacca Service Unit field technicians. Collected survey points were converted from the IHS modified Arizona State Plane East Ground system to the regular Arizona State Plane East Grid system using Trimble Business Center software. Final alignments may differ from this analysis and any such change(s) may alter elevations. For that reason, pipe pressure class ratings will need to be re-confirmed during the 50% Construction Document Review. Portions of the pipeline routing around the west side of First Mesa from near the Upper Mesa lagoon to the First Mesa East Tank has not yet been surveyed. Neither has the pipeline from FMCV to Lower Sipaulovi/Mishongnovi been surveyed. Elevations were estimated from Google Earth and USGS DEM and compared with a survey of the nearby road for those sections of the proposed alignment.

The design analysis was updated using actual CY-2017 water use data which was provided by the FMCV, Sipaulovi/Mishongnovi and Shungopavi water utility system personnel. Aggregate average water use for the 778 existing homes to be served by the HAMP is approximately 240 gallons per home per day (GPHD).

Water demand is based on reported water production from each water system. Flows for the unserved homes in the Second Mesa area have been included in the 2057 Demand calculations. The current and projected water production for the HAMP water system are shown in the Table below.

Current and Projected Water Demands

	No. of Connected Residential Services	2017 Reported Average Daily Residential Production Volume (Gal/Day)	Average Daily Non Residential Usage (Gal/Day)	2017 Average Daily Production (Gal/Day)	2017 Demand Based on 12-hour Pumping (gpm)	2057 Average Daily Production (Gal/Day)	2057 Demand Based on 12-hour Pumping (gpm)
*Shungopavi	160	25,572	1,000	26,572	36.9	85,270	118.4
Sipaulovi Mishongovi (lower)	107	22,074	1,000	23,074	32.0	45,060	62.6
**Sipaulovi Mishongovi (upper)	34	4,404	1,000	5,404	7.5	25,320	35.2
FMCV	477	150,376	16,091	166,467	231.2	306,965	426.3
Totals	778	202,425	19,091	221,516	308	462,615	643

*2057 numbers Include flows for the Cultural Center at 6000 gpd and 51 unserved homes
**2057 numbers Include flows for the 40 unserved homes in Second Mesa
2057 flows are based on 1.8% growth (on existing and unserved homes) per year from 2017

A well designed and properly constructed water transmission main can be expected to provide 50-years of service life, if not longer. WSTs, well pumps, and pressure boosting pumps may remain in service for 40, 10-20, and 10-20 years respectively. With such long periods of service to be provided, it is highly important that proper pipeline sizing to accommodate long-term future usage demands be considered. A 40-year design life was selected for the HAMP transmission main pipeline sizing. Thus, current population needs, as well as projected 40-year population trends, were evaluated to verify that pipelines of specific internal diameters will be able to carry more than enough flow well beyond 2018. Some system components, such as booster stations, will require up-sized pumps and other component re-design efforts after the HAMP has been operational for approximately 20-years. Tanks were sized for 20 years of storage capacity and well pumps are sized for both 20 and 40 years as the wells are anticipated to pump at the same rate, just for longer times each day in the future. Additional wells will be needed to allow for the pumps to continue to be pumped at the same rate.

<u>Hydraulic Modelling</u>

Hydraulic models were produced based on system analysis data. Model results are provides in Appendix E. The hydraulic models were utilized for the following purposes:

- The maximum and minimum pressures of the transmission main system during periods of minimum and maximum (min/max) flows were evaluated:
- An Extended Period Simulation (EPS) was modeled as a 96-hour period of typical system-usage time.
- The EPS is used to demonstrate how integrated tank cycling, well production, and booster station flows will function automatically in a coordinated manner.
  - Navajo Tribal Utility Authority (NTUA) demand hydrograph formats were used to independently simulate 24-hour water demands of the FMCV, Lower Sipaulovi/Mishongnovi, Upper Sipaulovi/Mishongnovi and the Shungopavi village water systems.
  - The models evaluated maximum water age characteristics within various parts of the HAMP water system.
- Actual pump curves for the proposed pump models which are listed on the schematic sheets in this report were integrated into the analysis.
  - Motor efficiencies from motor manufacturer's catalogues were incorporated.
  - System head curves were graphed by the modeling software for each well pump and booster station pump.
  - Pumping energy requirements were estimated.
  - Approximate costs for pumping power were estimated.

Three HAMP system design alternatives have been reviewed within this report. The three alternatives are the "Inverted-Y," the J-Hook," and the "Hybrid." The following system design schematic drawings can be referenced for the continuation of the design alternative comparisons which are further discussed in detail.

Common Design Elements

The three alternative designs share common operational elements and features.

The system alternatives were modeled for HAMP year-1 using currently available village system demand data as well as the projected usage demands of 91 Second Mesa homes which are not currently connected to any Hopi-village water service piping and also the demands of the Hopi Cultural Center. The year one demand estimates were increased by 1.8% each year up to 20-year and 40-year demand volumes.

The same 100-hp well pumps were used for each of the alternative's hydraulic analysis. Those pumps should meet the combined system demands of the four (4) HAMP PWS utilities (FMCV, Upper Sipaulovi/Mishongnovi, Lower Sipaulovi Mishongnovi. Shungopavi) for approximately 25-years from HAMP year-one. However, the additional wells will eventually need to be constructed in order to meet future long-term system demands.

The report entitled PROJECTED LONG-TERM PERFORMANCE OF HOPI ARSENIC MITIGATION PROJECT (HAMP) WELLS 2 AND 3, HOPI RESERVATION, ARIZONA by John W. Shomaker, PhD, CPG of John Shomaker & Associates, Inc. states that the Turquoise Trail Well Nos. 2 and 3 are capable of producing 415-gpm each with a predicted year 2035 drawdown of 698-feet for well no. 2 and 715-feet for well no. 3. It is intended that the well no. 2 pump intake should be set at least 720-feet below grade and that the well no. 3 intake screen should be set at least 740-feet below grade to facilitate future adaptation to a larger pump and motor assembly as will eventually be required. A six-inch (6") diameter drop pipe will be sufficient with 13-feet of dynamic head-loss to be produced at a theoretical maximum future pumping rate of 415 gpm from each well. Drawdowns for the hydraulic model are based on the constant-rate pumping test. Final design well production is expected to be at a rate similar to or below the pumping rates used during the constant-rate pumping test.

Based on verified 2014 static water levels of 423-feet and 453-feet below grade level (BGL) for Turquoise Trail Well Nos. 2 and 3 respectively, HAMP year-one system-head curves were developed for the selected well pumps. Upon system startup, Turquoise Trail Well Nos. 2 and 3 will each produce approximately 360 gpm when both pumps are running at the same time and while the new 310,000-gallon Hopi WST No. 1 is approaching its over-flow elevation level of 6166-feet MSL. When a single well is operating, the production rate should be approximately 370 gpm from either well. During HAMP year-one, and after the well pumps have run continuously for approximately 300-minutes, the pumping water level should drop to 538-feet BGL for well no. 2 and 578-feet BGL for well no. 3, i.e. 115-feet and 125-feet of draw-down for each well respectively. Those projected levels approximate the recommended average pumping cycle durations of 330-minutes per day in HAMP year-one. During those pumping cycles, production flows will reduce to 315-gpm from well no. 2 and 295-gpm from well no. 3.

Pumping water-levels in the Turquoise Trail Wells will subside over time. Well production may eventually reduce to 310-gpm from well no. 2 and 280-gpm from well no. 3. Energy calculations in the separate Cycling and Energy Cost report from the hydraulic analysis are based on pumping water levels of 5345-feet BGL and 5298-feet BGL, or 126-feet and 145-feet of combined aquifer depletion and drawdown within each well respectively relative to confirmed HAMP year-one static water levels. These drawdown values are conservative for calculating energy costs as they are drawdown levels when pumping at 300 gpm for 1000 minutes.

The designs would utilize 12-inch diameter IPS HDPE Standard Dimension Ratio (SDR) 13.5 piping to transport water from the Turquoise Trail Wells to Hopi Tank No. 1. That piping would also provide capacity for increased future flow when/if need be. Under each design alternative, all of the water that is required for the four served public water systems would first flow through Hopi Tank No. 1.

As evaluated in the hydraulic analysis, the tank-level cycling graph indicates that Hopi Tank No. 1 should be sized to provide average flows in excess of 700-gpm from Hopi Tank No. 1 without the tank being lowered excessively while the Turquoise Trail Wells simultaneously fill the tank at 610-gpm upon startup. During HAMP year-20, Hopi Tank No.1 would cycle about 2 times per day on average if it were set to re-fill when it was 75% full. Adding additional flow for the BIA systems would require increased water storage at the WST No. 1 site.

Water should flow to the FMCV's 250,000-gallon West Tank from the 500,000-gallon FMCV East Tank so that water will continuously circulate through FMCV's East (upper) hydraulic zone. By doing so, water in the east hydraulic zone will be continuously refreshed/replaced.

Approximately one-mile north of what will be the new FMCV West Tank and quite near to Polacca, transmission main water pressure will begin to exceed 190-psi. From this location, generally higher line pressures will be sustained and a maximum pressure approaching 210-psi will be produced near existing pressure reducing valve no. 5 (PRV-5) of the FMCV system (PRV-5 will not be connected to the high-pressure transmission piping.) As the transmission piping rises further up to FMCV East Tank base elevation of 5984-feet, pipeline water pressures will subside.

All of the unserved homes along HWY 264 and Route 17 would require wastewater service prior to being served by any of the existing or HUC water systems. ?

BIA/BIE Participation in the HAMP Process

If the combined public water system facilities of the United States Bureau of Indian Affairs (BIA) and the Bureau of Indian Education (BIE) determine that becoming participants in the HAMP water distribution system would be beneficial to their needs, a third HAMP well will need to be drilled and developed for production into the overall HAMP system transmission piping. Per Hopi Tribal Water Resources policy, an additional well in the Turquoise Trail area must be located a minimum of one-mile from any existing well(s). The location of an additional HAMP supply well has not been determined, but power availability will be an important criteria in such a siting/decision process.

Further, and if the BIA/BIE agencies should become HAMP participants, in order to accommodate the additional system demands which will be introduced to the HAMP transmission piping because of project expansion, much of the piping diameter between WST No. 1 and the FMCV East tank would need to be increased. This pipe-diameter increase would need be evaluated to permit a gravity-driven flow-rate of more than 875-gpm through the transmission main from Hopi Tank No. 1. That flow would be adequate to fill the FMCV East Tank and a new Hopi-BIA/BIE Tank which would be erected to service the needs of the BIA/BIE HAMP system extension eastward to Low Mountain Junction and the Hopi High School.

The HUC, the HAMP Villages and the BIA/BIE would be able to extend the capacity-life of the HAMP transmission mains beyond their 40-year projected beneficial usage by implementing metered usage and billing programs to all system customers and end-users.

For a variety of reasons, participation by the BIA/BIE in the HAMP must be decided prior to finalization of plans and specifications for the project construction phase. Implicit in that determination will be the need for additional funding to be secured in order to meet the additional capital cost of infrastructure which will be required specifically for the purpose of drilling a third HAMP Well and connecting that well to the HAMP transmission piping, constructing two (2) additional HAMP water storage tanks and also for expanding and extending the HAMP distribution system piping infrastructure to meet the needs of BIA/BIE facility water demands.

Design Specifics of the "Inverted-Y" Design Alternative

Under the "Inverted-Y" alternative, HAMP Booster Station No. 1 would be sited NEAR WST No. 1 where electrical power will be extended as part of the project. Approximately 26% of the water use would be pumped up to the Second Mesa villages. HAMP Booster Station No. 1 would utilize parallel 30-hp pumps for "boosting" pipeline pressure to transfer approximately 240-gpm of water through ten-inch (10") and eight-inch (8") diameter HDPE transmission main to 92,000-gallon Hopi Tank No. on Second Mesa. That pipeline would roughly follow the Route 17 and Route 4 roadway alignments. Hopi Tank No. 2 would be constructed in Upper Sipaulovi/Mishongnovi near the highest point above the Peach Lane area. A radio-telemetry system would activate HAMP Booster Station No. 1 when the water level in Hopi Tank No. 2 drops to approximately 75% of total capacity. That system would possibly require an intermediate radio-signal repeater to be installed at the existing radio tower location on the north side of Route 4 approximately 1-mile east of the Hopi Cultural center. From Hopi Tank No. 2, water would flow by gravity to the Upper Sipaulovi/Mishongnovi PWS, the Lower Sipaulovi/Mishongnovi PWS and also to HAMP Booster Station No. 2 near the Hopi Cultural Center.

HAMP Booster Station No. 2 will utilize parallel 5 hp pressure pumps to fill the elevated 250,000-gallon water storage tank in the Village of Shungopavi through an eight-inch (8") PVC main at a variable flow-rate of approximately 100-114 gpm. The PVC main would tie into the end of the existing Shungopavi water system. The PVC main would be turned over to the Shungopavi water system starting at the meter near Booster Station No. 2. Pipeline pressures downstream of HAMP Booster Station No. 2 would range from 55-psi to 75-psi. Existing hard-wired level-control floats in the elevated Shungopavi water storage tank would be utilized to energize the HAMP Booster Station No. 2 pumps using radio telemetry.

Including the Hopi Cultural Center and 51 currently unserved Shungopavi homes, the projected 12-hour average 40-year daily demand for the Shungopavi PWS is 118-gpm. The proposed location of HAMP Booster Station No. 2 is approximately 2-miles from Hopi Tank No. 2, but adequate suction head to the HAMP Booster Station No. 2 pumps will be sustained by the eight-inch (8") HDPE pipe sizing between HAMP Booster Station No. 1 and Hopi Tank No. 2. The minimum inlet pressure to the booster pumps will be approximately 24-psi.

The common fill and draw line from Booster Station No. 1 will be able to provide adequate pressure to all of the unserved Sipaulovi/Mishongnovi Route 17 homes. For one of those homes, pressure could drop as low as 11 psi however, so that home would require a low-maintenance individual variable-speed pressure booster pump in order to receive water service. Those homes would be served off of the HAMP/HUC main line unless a separate distribution line is extended from Hopi Tank No. 2.

Likewise, two (2) existing homes near the Hopi Tank No. 2 location would see minimum pressures of approximately 20-psi when that 55-foot tall structure is reduced to 80% capacity. All pressures on the transmission line would remain above 20-psi except for the referenced section near Hopi Tank No. 2.

The Hopi Utility Corporation could provide water to the Hopi Cultural Center from the eight-inch (8") diameter HDPE transmission with a branch-line to cross the Route 4 road and then extend for approximately 900 feet to land at the Cultural Center. Alternatively, the Shungopavi distribution system could also be extended to provide water to the Cultural Center. There are several homes that are in the vicinity of the cultural center. If a feasible sewer solution if found for those homes, they could also be served wither by the HAMP/HUC line or an extension from the Shungopavi distribution system.

From Hopi Tank No. 2 and the Upper Sipaulovi/Mishongnovi distribution system, a four-inch (4") diameter HDPE pipeline would transfer water down to the existing 75,000-gallon Lower Sipaulovi water storage tank through a series of three (3) pressure reducing valve-vault installations. The tank-filling process would be controlled by an altitude valve with flow control that would be installed at the base of the tank. The altitude valve would open and close in response to pre-determined tank-levels such as 80% to 100%. A 40-year projected flow-rate of 76-gpm would be adequate to supply the Lower Sipaulovi/Mishongnovi PWS, including the Second Mesa Day School if that facility should choose to become a customer of the Lower Sipaulovi/Mishongnovi PWS.

It is noted that the Lower Sipaulovi/Mishongnovi WST is more than 40-years old and has recently suffered a piping failure beneath it. That tank may soon be repaired and restored to service, but its long-term continued functionality is limited and thus it should be replaced with a new and larger tank. However, a new replacement tank in Lower Sipaulovi/Mishongnovi is not part of the "Inverted-Y" HAMP scope of work.

The sum of the average energy-cost requirements for the Turquoise Trail Well pumps (2 ea.) plus HAMP Booster Station No. 1 and No. 2, which are described for the "Inverted-Y" design in this report, is $115.89 per day. Specific manufacturer-listed pump and motor assembly efficiency ratings at stated design flows and system head conditions were included in the power-cost calculation. The energy analysis was performed assuming that all storage tanks are nearly full on day-one and the model was run as a 96-hour (4-day) simulation. Assumed daily energy costs would likely increase by a few dollars per day if the model was run for a longer simulation period.

<u>Design Specifics of the "J-Hook" Design Alternative</u>

All of the produced water will flow by gravity from Hopi Tank No. 1 to the FMCV East Tank. In the future, and as the FMCV East (upper) hydraulic-zone water demand grows, there will be operational advantages to keeping the FMCV East and West (upper and lower) hydraulic zones separated so that HAMP water can be delivered directly to the east tank and directly to the west tank in each respective zone.

The 193,000-gallon Hopi Tank No. 2 will be sited adjacent to the existing 250,000-gallon FMCV West Tank which is scheduled to be newly replaced in 2019 under an FMCV-Hopi Tribe/IHS project. Hopi Tank No. 2 will provide additional system storage which could be transferred directly into the FMCV West Tank through an altitude valve as needed. Hopi Tank No. 2 will also serve as the primary reservoir to feed the Lower Sipaulovi/Mishongnovi PWS and all of Second Mesa.

Flow-rates to Hopi Tank No. 2 and a potential HAMP-BIA/BIE Tank must be restricted in order to maintain positive pressure at the altitude valve to the FMCV East Tank. Flow-restriction can be achieved by utilizing reduced-size altitude valves on tank inlet piping assemblies and/or by installing flow restricting orifice plates on the discharge side of the tank-inlet altitude valves. Without BIA/BIE participation in the HAMP, the flow to Hopi Tank No. 2 should not exceed 850-gpm to avoid negative pressures at the FMCV East Tank. If BIA/BIE does participate in the HAMP, flows to Hopi Tank No. 2 should be further reduced by the amount of flow that the HAMP BIA/BIE tank receives plus any additional flow reduction resulting from friction losses between Hopi Tank No. 2 and the pipeline tee will "split" flows between the FMCV East Tank and the HAMP-BIA/BIE Tank.

From Hopi Tank No. 2 water will flow toward Lower Sipaulovi/Mishongnovi where the new 110,000-gallon Hopi Tank No. 3 will be constructed adjacent to the existing Lower Sipaulovi Tank. Hopi Tank No. 3 would fill directly from Hopi Tank No. 2 through an altitude valve located at the base of Hopi Tank No.3. Between Hopi Tank No. 2 and the Hopi Health Care Center (HHCC) in Polacca, the transmission main piping to Lower Sipaulovi/Mishongnovi would be 10-inch diameter HDPE. West of the HHCC, transmission piping can be reduced to 8-inch diameter HDPE. If the

BIA/BIE participates in the HAMP, the piping size between Polacca and Lower Sipaulovi/Mishongnovi should be re-evaluated. The proposed pipe sizes would permit unrestricted flows in excess of 300-gpm which would exceed projected 40-year system demands including all of Lower Sipaulovi/Mishongnovi, the entire projected demands for Upper Sipaulovi/Mishongnovi, Shungopavi and the Hopi Cultural Center. At this time, an undetermined amount of system modifications, including additional piping, would be needed to accommodate the connection of the Second Mesa Day School as a direct customer of the HAMP or alternatively as a customer of the Lower Sipaulovi/Mishongnovi PWS.

Hopi Tank No. 3 will be sized to feed the adjacent existing 75,000-gallon Lower Sipaulovi Tank. However, if that older WST cannot be replaced consequent to its recent piping failures, a cost effective alternative may be to increase the size of Hopi Tank No. 3 so that it will serve as a direct supply reservoir for the Lower Sipaulovi/Mishongnovi water distribution system while removing the existing 75,000-gallon Lower Sipaulovi Tank entirely.

From Hopi Tank No. 3, water will be pumped through HAMP Booster Station No. 1 up to the 92,000-gallon, 20-ft. tall Hopi Tank No. 4. Hopi Tank No. 4 would be constructed in Upper Sipaulovi/Mishongnovi near the highest point above the Peach Lane area. A radio-telemetry system would activate HAMP Booster Station No. 1 when the water level in Hopi Tank No. 4 drops to approximately 75% of total capacity.

HAMP Booster Station No. 1 would utilize parallel 40-hp pressure-pumps to “boost” 160 to 170-gpm to Hopi Tank No. 4, depending on the tank-level during pumping operations. The 40-year predicted 12-hour average daily water demand from HAMP Booster Station No 1 is 153-gpm. The Upper Sipaulovi and Upper Mishongnovi distribution systems will be equipped with HUC/HAMP master meters and backflow prevention assemblies to record volumetric usage so that each of those systems may be supplied from Hopi Tank No. 4 or directly from the HAMP Booster Station No. 1 when its pumps are energized. By doing so, the HAMP/HUC waterline to Hopi Tank No.4 will retain its status as a transmission main of the HAMP/HUC PWS.

The transmission piping between HAMP Booster Station No. 1 and Hopi Tank No. 4 will be eight-inch diameter ductile iron pipe for its lower-half length. The use of eight-inch pipe will reduce dynamic friction losses to nearly zero so that maximum pipeline pressure will be minimized. The highest pressure in the pipeline will be 275-psi as the pipe crosses under a small drainage-wash just west of HAMP Booster Station No. 1. As the pipeline continues upward along the Lower-Upper Sipaulovi/Mishongnovi roadway through the Toreva Lagoon area, pipeline pressure will be less than 220-psi and the pipe material will transition to HDPE. Pressures will continue to subside as the pipeline ascends further up to HAMP Tank No. 4 at an elevation of 6345-feet.

When the Upper Sipaulovi/Mishongnovi PWS is connected to the HAMP, the existing 15,000-gallon indoor horizontal-cylindrical fiber-glass tank, the 5-hp booster pump and the hydro-pneumatic pressure tank will become unnecessary because minimum dynamic pressures on the Upper Sipaulovi/Mishongnovi PWS will exceed 20-psi. Some homes at the lowest elevations of the upper-Second Mesa could experience pressures as high as 85-psi and may require an individual pressure reducing valve (PRV) to be installed on their service piping. Alternatively, a mainline-PRV just before the HUC/HAMP master meters and backflow prevention assemblies on village piping would also serve to reduce the pressure to less than 70 psi for approximately 30 residential water service connections per the Navajo IHS design criteria,. Pipeline sizing on the Upper Sipaulovi/Mishongnovi distribution piping should be field verified to ensure that existing diameters are no less than four-inches (4”). The referenced potential PRV installations are not shown on the HAMP “J-Hook” water system map, but should be incorporated into the HAMP project.

From the Hopi Tank No. 4 site, HAMP Booster Station No. 2 will be sited adjacent to Tank No. 4. HAMP Booster Station No. 2 will be equipped with parallel 7.5-hp pressure pumps. At 130-gpm, the minimum inlet pressure to those pumps will be 7-psi from the adjacent tank. Existing hard-wired level-control floats in the elevated Shungopavi water storage tank would be utilized to energize the HAMP Booster Station No. 2 pumps using radio telemetry. Other communication methods will also be explored at final design.

Depending on water levels in the 250,000-gallon elevated Shungopavi water storage tank, HAMP Booster Station No. 2 will deliver approximately 130-gpm directly to the Village of Shungopavi public water system through an eight-inch diameter PVC main which will minimize friction losses and line pressures. Pipeline pressures downstream of HAMP Booster Station No. 2 would range from 64-psi with the pumps on to approximately 60-psi with the booster pumps de-energized. The projected 40-year average daily demand flow for the Shungopavi PWS, including a possible connection to the Hopi Cultural Center and 51 additional unserved Shungopavi homes is 118-gpm.

The PVC main between Booster Station No. 2 and the Shungopavi system would be turned over to the Shungopavi water system starting at the meter near Booster Station No. 2. The Shungopavi distribution system could be extended to provide water to the Hopi Cultural Center. The Hopi Cultural Center is surrounded by unserved homes could also be served by a Shungopavi water distribution system extension. The HUC could also take on the Cultural Center as a customer along with the surrounding homes.

The "J-Hook" system design layout allows for redundant water storage tanks to be operated by different operators at two separate WST locations. The provision of HAMP/HUC tanks and village-owned storage tanks at adjacent locations will allow the HAMP/HUC system to remain separate and distinct from each of the village PWSs while providing operational flexibility when/if any of the storage tanks need to be taken offline for repair or maintenance. In addition, system operations can remain between the villages and the HUC, or not, depending on local preferences and agreements which may be enacted between individual villages and the HUC.

Under the "J-Hook" design layout, the sum of the average energy-cost requirements for the Turquoise Trail Well pumps (2 ea.) plus HAMP Booster Station No. 1 and No. 2, is $114.71 per day. Specific manufacturer-listed pump and motor assembly efficiency ratings at stated design flows and system head conditions were included in the power-cost calculations. The energy analysis was performed assuming that all storage tanks are nearly full on day-one and the model was run as a 96-hour (4-day) simulation. Assumed daily energy costs would likely increase by a few dollars per day if the model was run for a longer simulation period.

<u>Design Specifics of the "Hybrid" Design Alternative</u>

The "Hybrid" alternative will vary from the "Inverted-Y" in that 85 percent of the water is gravity fed toward FMCV from Hopi Tank No. 1 instead of 74 percent as in the "Inverted-Y." This provides an energy savings from the "Inverted-Y" because the Lower Sipaulovi/Mishongnovi water does not get pumped through the higher upper village first.

In the future, and as the FMCV East (upper) hydraulic-zone water demand grows, there will be operational advantages to keeping the FMCV East and West (upper and lower) hydraulic zones separated so that HAMP water can be delivered directly to the east tank and directly to the west tank in each respective zone. This would be achieved by installing an altitude valve between Hopi Tank No. 3 and the FMCV West Tank. That connection would not need to be made until the demand in the FMCV East pressure zone cycles the East Tank too many times a day.

The 110,000-gallon Hopi Tank No. 3 will be sited adjacent to the existing 250,000-gallon FMCV West Tank which is scheduled to be newly replaced in 2019 under an FMCV-Hopi Tribe/IHS project. Hopi Tank No. 3 will provide additional system storage which could be transferred directly into the FMCV West Tank through an altitude valve as needed. Hopi Tank No. 3 will also serve as the primary reservoir to feed the Lower Sipaulovi/Mishongnovi PWS.

Flow-rates to Hopi Tank No. 3 and a potential HAMP-BIA/BIE Tank must be restricted in order to maintain positive pressure at the altitude valve to the FMCV East Tank. Flow-restriction can be achieved by utilizing reduced-size altitude valves on tank inlet piping assemblies and/or by installing flow restricting orifice plates on the discharge side of the tank-inlet altitude valves. Without BIA/BIE participation in the HAMP, the flow to Hopi Tank No. 3 should not exceed 850-gpm to avoid negative pressures at the FMCV East Tank. If BIA/BIE does participate in the HAMP, flows to Hopi Tank No. 3 should be further reduced by the amount of flow that the HAMP BIA/BIE tank receives plus any additional flow reduction resulting from friction losses between Hopi Tank No. 3 and the pipeline tee will “split” flows between the FMCV East Tank and the HAMP-BIA/BIE Tank.

From Hopi Tank No. 3 water will flow toward Lower Sipaulovi/Mishongnovi where transmission pipe will tie into the end of the existing Lower Sipaulovi/Mishongnovi system. The connection to the Lower Sipaulovi/Mishongnovi system will be through a meter and solenoid valve. The solenoid valve will be controlled by radio signal from the Lower Sipaulovi WST. The Lower Sipaulovi WST will radio will transmit the water level of the tank. Between Hopi Tank No. 2 and the Hopi Health Care Center (HHCC) in Polacca, the transmission main piping to Lower Sipaulovi/Mishongnovi would be 8-inch diameter HDPE. West of the HHCC, transmission piping can be reduced to 6-inch diameter HDPE. If the BIA/BIE participates in the HAMP, the piping size between Polacca and Lower Sipaulovi/Mishongnovi should be re-evaluated. Those pipe sizes would permit unrestricted flows in excess of 170-gpm which would exceed projected 40-year system demands for all of Lower Sipaulovi/Mishongnovi. At this time, an undetermined amount of system modifications, including additional piping, would be needed to accommodate the connection of the Second Mesa Day School as a direct customer of the HAMP or alternatively as a customer of the Lower Sipaulovi/Mishongnovi PWS.

When the Upper Sipaulovi/Mishongnovi PWS is connected to the HAMP, the existing 15,000-gallon indoor horizontal-cylindrical fiber-glass tank, the 5-hp booster pump and the hydro-pneumatic pressure tank will become unnecessary because minimum dynamic pressures on the Upper Sipaulovi/Mishongnovi PWS will exceed 28-psi. Some homes at the lowest elevations of the upper-Second Mesa could experience pressures as high as 95-psi and may require an individual pressure reducing valve (PRV) to be installed on their service piping. Alternatively, a mainline-PRV just before the HUC/HAMP master meters and backflow prevention assemblies on village piping would also serve to reduce the pressure to less than 85 psi. Pipeline sizing on the Upper Sipaulovi/Mishongnovi distribution piping should be field verified to ensure that existing diameters are no less than four-inches (4”). The referenced potential PRV installations are not shown on the HAMP “J-Hook” water system map, but should be incorporated into the HAMP project.

Under the “Hybrid” alternative, HAMP Booster Station No. 1 would be sited NEAR WST No. 1 where electrical power will be extended as part of the project. Approximately 15% of the water use would be pumped up to the Second Mesa villages. HAMP Booster Station No. 1 would utilize parallel 20-hp pumps for “boosting” pipeline pressure to transfer approximately 150-gpm of water through eight-inch (8”) diameter HDPE transmission main to 92,000-gallon Hopi Tank No. 2, on Second Mesa. That pipeline would roughly follow the Route 17 and Route 4 roadway alignments. Hopi Tank No. 2 would be constructed in Upper Sipaulovi/Mishongnovi near the highest point above the Peach Lane area. A radio-telemetry system would activate HAMP Booster Station No. 1 when the water level in Hopi Tank No. 2 drops to approximately 75% of total capacity. That system would possibly require an intermediate radio-signal repeater to be installed at the existing radio tower location on the north side of Route 4 approximately 1-mile east of the Hopi Cultural center. From Hopi Tank No. 2, water would flow by gravity to the Upper Sipaulovi/Mishongnovi PWS and also to HAMP Booster Station No. 2 near the Hopi Cultural Center.

HAMP Booster Station No. 2 will utilize parallel 5 hp pressure pumps to fill the elevated 250,000-gallon water storage tank in the Village of Shungopavi through an eight-inch (8") PVC main at a variable flow-rate of approximately 116 gpm. The PVC main would tie into the end of the existing Shungopavi water system. The PVC main would be turned over to the Shungopavi water system starting at the meter near Booster Station No. 2. Pipeline pressures downstream of HAMP Booster Station No. 2 would range from 55-psi to 75-psi. Existing hard-wired level-control floats in the elevated Shungopavi water storage tank would be utilized to energize the HAMP Booster Station No. 2 pumps using radio telemetry.

Including the Hopi Cultural Center and 51 currently unserved Shungopavi homes, the projected average 40-year, 12-hour daily demand for the Shungopavi PWS is 118-gpm. The proposed location of HAMP Booster Station No. 2 is approximately 2-miles from Hopi Tank No. 2, but adequate suction head to the HAMP Booster Station No. 2 pumps will be sustained by the eight-inch (8") HDPE pipe sizing between HAMP Booster Station No. 1 and Hopi Tank No. 2. The minimum inlet pressure to the booster pumps will be approximately 24-psi.

The common fill and draw line from Booster Station No. 1 will be able to provide adequate pressure to all of the unserved Sipaulovi/Mishongnovi Route 17 homes. For one of those homes, pressure could drop as low as 11 psi however, so that home would require a low-maintenance individual variable-speed pressure booster pump in order to receive water service. Those homes would be served off of the HAMP/HUC main line unless a separate distribution line is extended from Hopi Tank No. 2.

Likewise, two (2) existing homes near the Hopi Tank No. 2 location would see minimum pressures of approximately 20-psi when that 55-foot tall structure is reduced to 80% capacity. Thus, those homes would also benefit from individual variable-speed pressure boosting pump-systems. All pressures on the transmission line and a separate future distribution line would remain above 20-psi except for the referenced section near Hopi Tank No. 2.

The Hopi Utility Corporation could provide water to the Hopi Cultural Center from the eight-inch (8") diameter HDPE transmission with a branch-line to cross the Route 4 road and then extend for approximately 900 feet to land at the Cultural Center. Alternatively, the Shungopavi distribution system could also be extended to provide water to the Cultural Center which is surrounded by un-served homes that will eventually be connected to one or the other of the two options (HAMP/HUC line or an extended Shungopavi distribution line.

Under the "Hybrid" design layout, the sum of the average energy-cost requirements for the Turquoise Trail Well pumps (2 ea.) plus HAMP Booster Station No. 1 and No. 2, is $110.06 per day. Specific manufacturer-listed pump and motor assembly efficiency ratings at stated design flows and system head conditions were included in the power-cost calculations. The energy analysis was performed assuming that all storage tanks are nearly full on day-one and the model was run as a 96-hour (4-day) simulation. Assumed daily energy costs would likely increase by a few dollars per day if the model was run for a longer simulation period.

Evaluation and Comparison of Design Option Life-Cycle Costs

General Observations

- The "Inverted-Y" design, the "J-Hook" design, and the "Hybrid" design will all function effectively from a hydraulic design perspective.
- Each design option represents a valid selection upon which to proceed with detailed HAMP-system design efforts.
- Each of the design alternatives would utilize approximately the same amount of pumping energy with the "Hybrid" being the least.
- All pressure reducing valve (PRV) will eventually fail. Such failures can permanently damage downstream piping by allowing higher pressures to develop than what the downstream piping may be rated to handle.
- Fail safe mechanisms, such as pressure relief valves to reduce pipe over-pressurization potential, could be put in place but such measures will tend to increase system complexity and maintenance requirements.
- The "Inverted-Y" design will require three (3) critical PRV vault installations to moderate water-pressure from Upper Sipaulovi/Mishongnovi down to Lower Sipaulovi/Mishongnovi. Those PRV installations must be adjusted to complement each other and then be inspected and maintained on a regular basis for that purpose.
- The "Inverted-Y" and "Hybrid" designs will each utilize a single pressure reducing valve for a branch of the Upper Sipaulovi/Mishongnovi distribution systems. That PRV will function independently and will not need to operate in conjunction with any other valves or devices.
- The "Inverted-Y" design would utilize two altitude valves for tank-level control.
- The "J-Hook" design will utilize three altitude valves for tank-level control.
- The "Hybrid" design would utilize two altitude valves and a solenoid valve for tank-level control.
- If an altitude valve is not set up properly or functioning correctly, it may possibly overflow the tank which it is designed to regulate.
- The reason that the "J-Hook" will include four (4) new HAMP/HUC water storage tanks to provide greater system redundancy and operational flexibility. Three of those tanks will be filled by altitude valves.
- Altitude valves are considered to be quite reliable and they do not fail in a catastrophic manner. The worst-case scenario for an altitude valve is failure to open (tank does not fill) or failure to close (tank overflows). When/if an altitude valve fails, the tank which it fills can easily be operated manually until the valve has been repaired.

Other Assumptions and Constraints

1. The HAMP/HUC waterline is designed primarily as a regional water transmission system and is well-suited to remain separated as a distinct water supply-source for each of the individual village PWSs in First and Second Mesa. The HAMP/HUC waterline may provide service connections to remote houses that the village water systems do not reach. This would be an agreement between the homeowner and the HUC.
2. Because the HAMP is intended to function as a series of connected regional transmission main segments, an over-all peak-factor was not used in the minimum dynamic pressure hydraulic analysis. The areas of 8-inch PVC that will be turned over to the village water systems were evaluated separate from this report and were found to have negligible effect on pressures with a peak factor.
3. Pipeline sizing for the year 2057 is based on flows needed for a 12-hour average daily pumping cycle per the Navajo IHS Design Criteria and the actual pump flow that is necessary to deliver/meet a specific demand. The 12-hour average daily pumping cycle allows for some extra pumping time on days within peak usage months such as June, July and August.
4. Hopi Cultural Center water usage was estimated and included in the design.
5. A future connection, or spur-line, to Kykotsmovi was not considered in the design.
6. An annual growth rate of 1.8% was utilized for the entire HAMP system area population. This is a modest growth projection compared to the 2000-2010 U.S. Census Data that showed 2.61% population growth. Supporting the 1.8% annual growth rate is the 2013-2017 village utility water usage data that shows an approximate 2% water demand increase over a consecutive four (4) year period.
7. Without considering potential BIA/BIE system demands, the FMCV is the largest HAMP PWS and it will utilize approximately 75% of the Turquoise Trail Wells production water.
8. A maximum Hopi Tank No. 1 overflow (OF) water level height of 6166-feet is needed to meet the 30-year gravity flow requirement to the FMCV East Tank. A 6166-foot OF elevation will also accommodate BIA/BIE demands if those systems participate in the HAMP, with increased pipe sizing between WST No. 1 and FMCV East Tank.
9. The implementation of metered rates by the FMCV (and all other HAMP PWSs) will reduce future demand usage to a significant degree.
10. Actual inside pipe diameters were used for the hydraulic analyses.
11. PRV locations need to be field verified. If they are moved from the locations of this model, the calculated PRV inlet and outlet settings will need to be adjusted to the new elevation(s).
12. Still pending is the approval of Hopi Tank #4, the tank above Peach Lane. That tank height will need to be 55-feet to meet pressure needs at downstream houses. A 50-foot tank height could suffice, but it would be at the border-line of being able to serve several more homes which would then require individual variable speed pressure booster pump-systems to be installed at each of those low-pressure homes. The location of the tank will be presented to the Village of Shungopavi for approval or modification of the location. It may be effective to mark the tank location in the field with a marker visible from Shungopavi, to provide a more realistic visualization of the proposed tank. That way, Shungopavi leaders would be able to see how the tank would impact their view from the west looking northeast.
13. A backup emergency water source to the Route 17 Hopi Tank No. 4 from the Shungopavi Tank could be discussed and a future normally closed valve from the Shungopavi

distribution system could be installed on the HAMP Booster Station No. 2 bypass line. There would also need to be a PRV installed on the bypass line to reduce pressure from Shungopavi to the Upper Sipaulovi/Mishongnovi homes.

14. All design decisions which may minimize pump energy usage should be studied and utilized to the maximum extent which is determined to be practical.
15. Simplicity of control systems and controls-logic should be considered as an important advantage when comparing any possible layouts and designs.
16. Fire-flow analysis was not conducted as part of this hydraulic modeling exercise. However, it should be understood that fire flows to the Hopi Cultural Center would not be provided by the HUC/HAMP transmission main from Hopi Tank No. 4 because the water pressure at some Second Mesa homes would then drop to well below 20 psi. An undetermined amount of fire flow could possibly be made available from the Shungopavi elevated storage tank distribution line if the Hopi Cultural Center and Shungopavi Village developed a specific agreement for that purpose. Alternatively, the Hopi Cultural Center might be able to develop a fire-flow reserve system by modifying its existing standpipe and pressure system into a separate fire-flow piping circuit that would be isolated from the on-site potable piping systems which exist on that property.
17. Power needs for the Turquoise Trail Wells will be provided through an NTUA powerline extension. As a significant contribution to the HAMP effort, the Hopi Tribe has committed to meeting the cost of extending NTUA power to the Turquoise Trail Wells.
18. At HAMP funding-budget expense, APS will be the source of power required for the Hopi Tribe's 2nd Mesa Booster Station.
19. At HAMP funding-budget expense, NTUA will be the source of power required for Booster Station 1 located at Hopi Tank No. 1 on both the "Inverted-Y" and "Hybrid" variations of the alignment. The power would be extended from Turquoise Trail Well No. 3.
20. The location of a future HAMP well to meet possible BIA/BIE demands is not known.
21. Sizing of piping to connect a future BIA/BIE-funded HAMP well to Hopi Tank No. 1 is uncertain.

Evaluation of Alternatives

As presented, the "2014 PER Inverted-Y" and the "J-Hook" design alternatives were evaluated based on the following factors:

1. Ease of Operation

   The "Inverted-Y" would rely on three (3) pressure reducing valves between Upper Sipaulovi/Mishongnovi and Lower Sipaulovi/Mishongnovi. two (2) altitude valves for tank-level control, and a long-range radio-telemetry signal system from the Second Mesa Hopi Tank No. 2 to HAMP Booster Station No. 1 near Hopi Tank No. 1. A radio signal repeater would likely be necessary as a part of the Hopi Tank No. 2 level-control system. The "J-Hook" would rely on three (3) altitude valves for tank-level control. The "J-Hook" may also need a repeater for controls between Hopi Tank No. 3 next to the Lower Sipaulovi tank and Hopi Tank No. 4. Both design alternatives would utilize a short line of site telemetry system between the elevated Shungopavi WST and Hopi Booster Station No. 2.

   Altitude valves present less risk to system piping than pressure reducing valves.

2. Construction Costs

   Please reference the capital cost estimates for each of the two (2) design in Appendix A of this report. The "J-Hook" alternative is estimated to cost $19.03M, the "Inverted-Y" is estimated to cost $20.61M, and the "Hybrid" is estimated to cost $20.5M. Each of these estimates exclude power line costs to the wells which would be met by the Hopi Tribe/HUC. Relative to available project funding, the "Inverted-Y" has a funding shortfall of $5.61M with no available solution to meeting that shortfall of $1.61M. Relative to available project funding, the "Hybrid" has a funding shortfall of $5.5M with no available solution to meeting the shortfall of $1.5M. At the same time, the lower-cost "J-Hook" alternative has an identified funding shortfall of approximately $4M which will likely be addressed from the IHS and the USEPA over the next two annual sanitation facilities construction funding cycles.

3. Lifecycle Costs

   Please reference the life cycle cost analysis for each of the three (3) design alternatives in Appendix C of this report. The 20 year life cycle present worth cost calculation for the "Inverted-Y" design alternative is $18.28M. The present worth cost calculation for the "J-Hook" design alternative is $17.56M. The present worth cost for the "Hybrid" is $18.22M.

4. Energy Costs

   Pumping costs will make up nearly all of the HAMP system operational energy costs. Based on estimated unit power costs of $0.10/kWh, the "Inverted-Y" has been calculated to generate a pumping energy cost of $115.89 per day during HAMP year-one. Utilizing the same assumptions, the "J-Hook" alternative has been calculated to generate a pumping energy cost of $114.71 per day and the "Hybrid" $110.06 per day. Those electrical rates equate to $42,300 for the "Inverted-Y" in HAMP year-one, $41,870 for the "J-Hook" alternative, and $40,170 for the "Hybrid." Both design options demonstrate a significant decrease in energy costs from values which were originally reported in the 2012 Hopi Arsenic Mitigation Project Strategic Plan document which had predicted an energy cost of $105,000 during HAMP year-one.

5. Rehabilitation and Replacement (R&R) Costs

   The annual rehabilitation and replacement costs for the first 20 HAMP-years were calculated for each alternative. The results are shown on the HAMP R&R Present Value spreadsheets for each alternative. The "Inverted-Y" has an estimated annual replacement cost of $40,349 and an annual rehabilitation cost of $39,960. The "J-Hook" alternative shows an estimated annual replacement cost of $38,580 and an annual rehabilitation cost of $43,820. The "Hybrid" has an estimated annual replacement cost of $38,580 and an annual rehabilitation cost of $41,743. For the "Inverted-Y", annual R&R costs total to $80,310, the"J-Hook" alternative presents total annual R&R costs of $82,400, and the "Hybrid" R&R costs are $80,320.

6. <u>NEPA and Cultural Constraints</u>

For each referenced design alternatives, Hopi Tank No. 1 will be located in a cleared area from the 2014 Environmental Assessment. Portions of the pipeline route from the FMCV West Tank to the FMCV East Tank will need archeological clearance, but impacts may be minimized by following the alignments of existing utilities within the highway AZ 264 corridor. There have been other small alignment modifications to modify the route of the pipeline alignment such as moving part of the alignment between Hopi Tank No. 1 and FMCV to the east, putting it upstream of an earthen dam. This also straightened the alignment, reducing pipe length. The "J-hook" will now follow the north side of Hwy 264. The ADOT right of way has previously been surveyed and will likely require minimal additional review.

The Upper Sipaulovi/Mishongnovi Hopi Tank (No. 2 or No. 4) along Route 17 presents previously expressed concerns for view-shed impact, primarily from Village of Shungopavi residents. All three of the design scenarios would be best served by siting the tank at that location due to the reasons discussed previously in this report. The site above Peach Lane was cleared in the 2014 Environmental Assessment addendum 1, but any possible impact to the view shed should be discussed with the Village of Shungopavi. The tank would be 55-feet in height by 17-feet in diameter on the "Inverted-Y" and "Hybrid" alternatives. The tank would be 20-feet in height by 31-feet in diameter on the "J-hook" alternative. A booster station would also be adjacent to the tank on the "J-hook" alternative. The tank can be painted to blend in with the adjacent terrain in order to minimize its visual the impact.

In general, final NEPA approval efforts for either design alternative are expected to advance ahead of previously assumed projected schedules.

7. <u>Construction Schedule</u>

The "Inverted-Y" design option will require that approximately 32,000-feet of additional pipeline be installed compared to the "J-hook." The "Hybrid" design option will require that approximately 44,000-feet of additional pipeline be installed compared to the "J-hook." Per USGS soils-maps, the "Inverted-Y" and "Hybrid" pipeline routes are also likely to require twice as much sandstone excavation in comparison to the "J-Hook" design alternative. Conversely, the "J-Hook" design alternative also requires that two (2) additional water storage tanks must be constructed.

Water storage tanks can be constructed independently by different crews at the same time that pipeline installations are underway. However, those tanks cannot be hydro-statically tested until pipeline construction has been completed to deliver water to the tank site(s).

8. <u>Ease of Construction</u>

The "Inverted-Y" and "Hybrid" are routed through 60,000 lineal-feet of sandstone and rock outcrop features mostly along Route 4. The "J-Hook" alternative presents 18,000 lineal-feet of sandstone excavation, primarily in Second Mesa along highway AZ 264 and Route 17. The "J-Hook" and "Inverted-Y" both have pipeline constructed through the Toreva area from Lower Sipaulovi/Mishongnovi to Upper Sipaulovi/Mishongnovi. This area will be difficult construction with some risk. The "Hybrid" alternative does not go through the Toreva area.

The “Inverted-Y” has a total of 206,300 lf of pipe to be installed, The “J-hook” has a total of 171,200 lf of pipe to be installed, and the “Hybrid” has a total of 217,700 lf of pipe to be installed.

9. Village/Tribe Preference

   The HUC has expressed concerns, on behalf of the Tribe, that the preference of the Tribe is to maintain an alternative that as closely as possible follows the 2014 approved PER alignment. Of the three alternatives, the updated “Inverted-Y” most closely follows the original route and therefore would be considered the preference. The “Hybrid” is a close second because is closely follows the original alignment with the exception of the lower leg to connect to the Lower Sipaulovi system from the First Mesa area. The HUC has expressed a desire to explore this option through their draft report procured from D.B. Stephens that had a similar alternative. In several village and Tribal meetings, community members have expressed discontent for switching from the “Inverted-Y” alignment.

10. Lower Pressures

    Low pressures help project costs by reducing the thickness of the pipe. The “J-Hook” has the areas with the highest pressures. The highest pressure is seen at the downstream side of the Lower Sipaulovi Booster Station No. 1. The pressures are near 272 psi at the highest. It is likely that ductile iron pipe would be used in that area to add extra pressure protection. The “Hybrid” and the “Inverted-Y” both have similar pressures. The peak pressure those two alternatives between the wells and First Mesa East Tank is along HWY 264 at about 213 psi. SDR 9 HDPE can withstand this pressure without any problem. The “Hybrid” has a slight advantage over the “Inverted-Y” because there is less SDR 9 pipe required in the shared areas of high pressure.

11. Future Redundancy

    The “J-Hook” alternative includes an additional WST adjacent to the FMCV West Tank and another new WST to be constructed near the existing Lower Sipaulovi Tank. These WSTs will provide the HUC/HAMP system and the local village systems with the ability to redundantly rely on parallel back-up facilities when/if a WST must be removed from service for general maintenance, repairs, and possibly eventual replacement in some instances. It is noted that the Lower Sipaulovi Tank is more than 45-years old and the piping beneath it has recently failed, even though that WST was completely re-coated/rehabilitated internally in 2014, less than five (5) years-ago. The “Hybrid” alternative provides one parallel WST adjacent to the FMCV West Tank.

12. Weighting Decision

    System operations are critical to the longevity of the pipeline even as the budget for the HAMP design effort remains limited. Costs to the end user should be minimized by keeping the HAMP-system energy consumption as low as possible. Design alternative “weight” factors from one to three (1 – 3) were assigned to each Evaluation of Alternatives criteria.

Design Alternatives Final Weighted Scoring Matrix

Engineering, Construction and O&M Evaluation							
Criteria	Weight Factor	"Inverted-Y" Criteria Score (1 – 10)	Weighted Score	"J-Hook" Criteria Score (1 – 10)	Weighted Score	"Hybrid" Criteria Score (1 – 10)	Weighted Score
Ease of Operation	3	7	21	8	24	9	27
Construction Cost	3	8	24	9	27	8	24
Lifecycle Cost	1	8	8	9	9	8	8
Energy Cost	3	7	21	8	24	9	27
R&R Cost	2	8	16	7	14	9	18
NEPA and Cultural Constraints	3	9	27	7	21	8	24
Construction Schedule	2	7	14	9	18	8	16
Ease of Construction	3	6	18	7	21	9	27
Village/Tribe Preference	3	7	21	5	15	8	24
Lower Pressures	2	8	16	6	12	9	18
Future Redundancy	1	6	6	9	9	8	8
		Totals >>>	192	Totals >>>	194	Totals >>>	221

Conclusion/Recommendation

Three (3) separate HAMP system design alternatives have been evaluated in considerable detail. There are pros and cons to each alternative. If total capital cost was not a compelling criteria for design selection, the "Hybrid" would be the preferred design alternative selection.

However, capital costs are significantly determinant factors in this selection process as also are annual operational costs which are $2,120 per year apart in favor of the "Hybrid" design alternative. The "Inverted-Y" alternative has the second best annual operating cost.

Cost Item	"Inverted-Y"	"J-Hook"	"Hybrid"
Annual Pumping Costs	$42,300	$41,870	$40,170
Annual R&R	$80,310	$82,400	$80,320
Totals>>>	$122,610	$124,270	$120,490

Operational benefits and dis-benefits, or pros and cons, between the three (3) design alternatives have been discussed in the four (4) report document sections above which are entitled:

- *General Observations*
- *Other Assumptions and Constraints*,
- *Evaluation of Alternatives*, and
- *Design Alternatives Final Weighted Scoring Matrix*

As presented on page 22, the General Observations tends to favor the "Hybrid" design alternative primarily based on the operational and water system security differences between a reliance on pressure reducing valves, lower operating pressures, and lowered construction risk with the elimination of the line through Toreva.

On page 23 there are 21 items listed under Other Assumptions and Constraints. Upon reviewing those 21 items, no consensus to favor either design alternative is obvious or noted.

Beginning on page 25, the Evaluation of Alternatives section is quite detailed and focuses on capital costs, life-cycle costs and operational cost differences between the three designs.

To follow up on the evaluation of alternatives, the Design Alternatives Final Weighted Scoring Matrix on page 28 provides a tabular numeric summary of the 11 items which are presented under Evaluation of Alternatives. Within that matrix, weighting factors which were quantified during a group discussion of IHS/EADO engineers, have been assigned to each of the evaluation criteria and scores which are specific to each design alternative have also been assigned to each evaluation criteria.

For the three design alternatives, the evaluation criteria scores have been multiplied by their individually assigned weighting factors to produce a value which is listed as "Weighted Score". Of the ten (12) weighted scores which were derived for the design alternatives, the "Hybrid" design presents a slight numeric advantage in six (6) of the criteria. Out of a possible 260 points, the final totalized tally for weighted scores was 192 for the "Inverted-Y" design option, 194 for the "J-Hook" alternative, and 221 for the "Hybrid" alternative.

Up to this point in the evaluation of design alternatives there seems to be a slight, but not overwhelming, advantage/benefit to proceeding with the "Hybrid" design in lieu of the "Inverted-Y" and "J-hook" alternatives. The final considerations for an evaluation of this type should therefore be capital costs relative to available project funding. From that perspective, the design alternative choice would be the "J-Hook" because full and total funding for that option has been secured/identified by a combination of IHS, USEPA and Hopi Tribe funds. At the same time, the "Inverted-Y" and "Hybrid" designs still present an unresolved $1.5-1.63M funding shortfall. Should the Tribe choose an alternative with a funding shortfall, the project will proceed through design and construction while the remaining funding is sought and secured.

Appendix A

Cost Estimates

UPDATED "2019 INVERTED Y" COST ESTIMATE

Schedule A: Planning and Design

Item	Description	Qty	Units	Unit Cost	Total
1	Geotechnical Investigations	1	LS	$ 75,000	$ 75,000
2	Archaeological Survey and Monitoring	1	LS	$ 15,000	$ 15,000
				Pre-Construction Total:	**$ 90,000**

Schedule B: Construction

Item	Description	Qty	Units	Unit Cost	Total
	Power, Generators				
3	200 KW Mobile Generator (Wells)	1	EA	$ 125,000	$ 125,000
4	100 KW Mobile Generator (Booster Sta)	1	EA	$ 75,000	$ 75,000
5	Power Extension (Booster 1)	1	EA	$ 804,000	$ 804,000
6	Power Extension (Booster 2)	1	EA	$ 100,000	$ 100,000
	Water Mains, Gate Valves, ARVs, PRVs				
7	SWPPP	1	LS	$ 32,400	$ 32,400
8	12" HDPE, SDR 9 IPS	25,359	LF	$ 58.00	$ 1,470,822
9	12" HDPE, SDR 11 IPS	27,699	LF	$ 53.00	$ 1,468,047
10	12" HDPE, SDR 13.5 IPS	15,820	LF	$ 48.00	$ 759,360
11	10" HDPE, SDR 9 DIPS	16,973	LF	$ 46.00	$ 780,758
12	10" HDPE, SDR 11 DIPS	11,286	LF	$ 42.00	$ 474,012
13	10" HDPE, SDR 13.5 IPS	32,484	LF	$ 39.00	$ 1,266,876
14	8" HDPE, SDR 13.5 IPS	57,326	LF	$ 28.00	$ 1,605,128
15	8" C900 PVC DR 25	5,569	LF	$ 39.00	$ 217,191
16	6" HDPE, SDR 11 IPS	183	LF	$ 28.00	$ 5,124
17	6" HDPE, SDR 13.5 IPS	5,073	LF	$ 26.00	$ 131,898
18	4" HDPE SDR 9 IPS	4,709	LF	$ 25.00	$ 117,725
19	4" HDPE SDR 11 IPS	3,786	LF	$ 23.00	$ 87,078
20	Rock Excavation	60,000	LF	$ 21.00	$ 1,260,000
21	12" Gate Valves	16	EA	$ 3,500	$ 56,000
22	10" Gate Valves	14	EA	$ 3,000	$ 42,000
23	8" Gate Valves	18	EA	$ 2,250	$ 40,500
24	6" Gate Valves	6	EA	$ 2,000	$ 12,000
25	4" Gate Valves	6	EA	$ 1,800	$ 10,800
26	Flush Valve	19	EA	$ 8,000	$ 152,000
27	Pressure Reducing Valve & Vault	4	EA	$ 20,000	$ 80,000
28	Air Relief Valves	30	EA	$ 5,000	$ 150,000
	Pumps and Motors				
29	100 hp Submersible Well Pump (385S1000-12), Drop Pipe, Building, Piping, Meter	2	EA	$ 210,000	$ 420,000
30	30 hp Booster Station CR45-4-2, Piping, Meter	1	EA	$ 150,000	$ 150,000
31	5 hp Booster Station CR20-2, Piping, Meter	1	EA	$ 100,000	$ 100,000
	Tank Level Control and Connections				
32	Altitude Valve & Vault	2	EA	$ 35,000	$ 70,000
33	Master Meter	6	EA	$ 10,000	$ 60,000
34	Existing Tank Interconnection	2	EA	$ 10,000	$ 20,000
35	Electrical/Telemetry	3	EA	$ 200,000	$ 600,000
	Disinfection Facilities				
36	HAMP Disinfection Facility	2	EA	$ 30,000	$ 60,000
	Wash Crossing				
37	Directional Bore - Wash	500	LF	$ 180	$ 90,000
	Road Excavation and Repair				
38	Road Excavation and Repair - Unpaved Open Cut	2,250	LF	$ 250	$ 562,500
39	Road Excavation and Repair - Paved Open Cut	2,500	LF	$ 300	$ 750,000
40	Paved Road Crossing - Jack & Bore	1,800	LF	$ 200	$ 360,000

Item	Description	Qty	Units	Unit Cost	Total
	Water Storage Tanks				
41	310,000 gallon Hopi Tank #1 Route 8, 24' H x 48' D	1	LS	$ 750,000	$ 750,000
42	150,000 gallon Hopi Tank #2, at Route 17, 55' H x 22' D	1	LS	$ 480,000	$ 480,000
			Construction Total:		**$ 15,796,219**

Schedule C: Post Construction

Item	Description	Qty	Units	Unit Cost	Total
43	1-Year Start-Up Assistance	24	DAYS	$ 500	$ 12,000
44	O&M Materials, Equipment and Space	1	LS	$ 425,000	$ 425,000
45	O&M Manual Development	1	LS	$ 40,000	$ 40,000
			Post Construction Total:		**$ 477,000**

	Total Cost Estimate	V31 Costs	Future Costs
Planning & Design Total (Schedule A)	**$ 90,000**	**$ 90,000**	**$ 0**
Construction Total (Schedule B)	**$ 15,796,219**	**$ 10,608,000**	**$ 5,188,219**
Post Construction Total (Schedule C)	**$ 477,000**	**$ 320,331**	**$ 156,669**
Contingencies, 10% (Schedules A, B, & C)	**$ 1,636,322**	**$ 1,101,833**	**$ 534,489**
Subtotal	**$ 17,999,541**	**$ 12,120,164**	**$ 5,879,377**
TERO/Tribal Tax, 3.0%	**$ 539,986**	**$ 363,605**	**$ 176,381**
Tribal Administrative Support Fee*	**$ 364,491**	**$ 244,653**	**$ 119,838**
Tribal Fees	**$ 904,477**	**$ 608,258**	**$ 296,219**
IHS Engineering Program Support, 10% (EPS)	**$ 259,718**	**$ 259,718**	
IHS Project Technical Support Fee, 8% (PTS)	**$ 1,439,963**	**$ 969,613**	**$ 470,350**
Total Cost	**$ 20,603,699**	**$ 13,957,753**	**$ 6,645,946**
Use Total Cost of	**$ 20,604,000**	**$ 13,958,000**	**$ 6,646,000**
IHS Funded		**$ 11,000,000**	
EPA FY 18 Commitment		**$ 3,000,000**	
U62 EPA Funding			**$ 985,000**
Shortfall			**$ 5,661,000**
NTUA Power Line Extension (by Tribe/HUC)	**$ 1,100,000**		

"J-HOOK" COST ESTIMATE

Schedule A: Planning and Design

Item	Description	Qty	Units	Unit Cost	Total
1	Geotechnical Investigations	1	LS	$ 75,000	$ 75,000
2	Archaeological Survey and Monitoring	1	LS	$ 15,000	$ 15,000
				Pre-Construction Total:	**$ 90,000**

Schedule B: Construction

Item	Description	Qty	Units	Unit Cost	Total
	Power, Generators				
3	200 KW Mobile Generator (Wells)	1	EA	$ 125,000	$ 125,000
4	150 KW Mobile Generator (Booster Sta)	1	EA	$ 90,000	$ 90,000
5	Reroute Electrical (Booster 1)	1	EA	$ 35,000	$ 35,000
6	Power Extension (Booster 2)	1	EA	$ 100,000	$ 100,000
7	**Water Mains, Gate Valves, ARVs, PRVs**				
8	SWPPP	1	LS	$ 32,400	$ 32,400
9	14" HDPE, SDR 9 DIPS	9,132	LF	$ 71.00	$ 648,372
10	14" HDPE, SDR 11 DIPS	5,808	LF	$ 64.00	$ 371,712
11	12" HDPE, SDR 9 DIPS	15,668	LF	$ 58.00	$ 908,744
12	12" HDPE, SDR 11 DIPS	19,495	LF	$ 53.00	$ 1,033,235
13	12" HDPE, SDR 13.5 DIPS	51,223	LF	$ 48.00	$ 2,458,704
14	10" HDPE, SDR 11 DIPS	5,178	LF	$ 42.00	$ 217,476
15	10" HDPE, SDR 13.5 DIPS	12,557	LF	$ 39.00	$ 489,723
16	8" HDPE, SDR 9 DIPS	1,906	LF	$ 33.00	$ 62,898
17	8" HDPE, SDR 13.5 DIPS	30,337	LF	$ 28.00	$ 849,436
18	8" Ductile Iron Pipe	3,809	LF	$ 42.00	$ 159,978
19	8" C900 PVC DR 25	15,755	LF	$ 39.00	$ 614,445
20	6" HDPE, SDR 13.5 DIPS	281	LF	$ 26.00	$ 7,306
21	Rock Excavation	18,000	LF	$ 21.00	$ 378,000
22	14" Gate Valves	5	LF	$ 4,500	$ 22,500
23	12" Gate Valves	20	EA	$ 3,500	$ 70,000
24	10" Gate Valves	6	EA	$ 3,000	$ 18,000
25	8" Gate Valves	14	EA	$ 2,250	$ 31,500
26	6" Gate Valves	10	EA	$ 2,000	$ 20,000
27	Flush Valve	15	EA	$ 8,000	$ 120,000
28	Pressure Reducing Valve & Vault	1	EA	$ 20,000	$ 20,000
29	Air Relief Valves	35	EA	$ 5,000	$ 175,000
	Pumps and Motors				
30	100 hp Submersible Well Pump (385S1000-12), Drop Pipe, Building, Piping, Meter	2	EA	$ 230,000	$ 460,000
31	40 hp Booster Station, Piping, Meter	1	EA	$ 175,000	$ 175,000
32	7.5 hp Booster Station, Piping, Meter	1	LS	$ 100,000	$ 100,000
	Tank Level Control and Connections				
33	Altitude Valve & Vault	3	EA	$ 35,000	$ 105,000
34	Master Meter	10	EA	$ 10,000	$ 100,000
35	Existing Tank Interconnection	4	EA	$ 10,000	$ 40,000
36	Electrical/Telemetry	3	EA	$ 200,000	$ 600,000
	Disinfection Facilities				
37	HAMP Disinfection Facility	2	EA	$ 30,000	$ 60,000
	Wash Crossing				
38	Directional Bore - Wepo Wash (3x)	1,500	LF	$ 180	$ 270,000
	Road Excavation and Repair				
39	Road Excavation and Repair - Unpaved Open Cut	2,000	LF	$ 250	$ 500,000
40	Road Excavation and Repair - Paved Open Cut	2,500	LF	$ 300	$ 750,000
41	Paved Road Crossing - Jack & Bore	1,800	LF	$ 200	$ 360,000
	Water Storage Tanks				
42	310,000 gallon Hopi Tank #1 Route 8, 24' H x 48' D	1	LS	$ 750,000	$ 750,000

Item	Description	Qty	Units	Unit Cost	Total
43	193,000 gallon Hopi Tank #2 FMCV, 42' H x 28' D	1	LS	$ 510,000	$ 510,000
44	110,000 gallon Hopi Tank #3 Lower Siplvi, 24' H x 28'D	1	LS	$ 360,000	$ 360,000
45	92,000 gallon Tank at Hopi Tank #4 Rt 17, 56' H x 17' D	1	LS	$ 325,000	$ 325,000
			Construction Total:		**$ 14,524,429**

Schedule C: Post Construction

Item	Description	Qty	Units	Unit Cost	Total
46	1-Year Start-Up Assistance	24	DAYS	$ 500	$ 12,000
47	O&M Materials, Equipment and Space	1	LS	$ 425,000	$ 425,000
48	O&M Manual Development	1	LS	$ 40,000	$ 40,000
			Post Construction Total:		**$ 477,000**

	Total Cost Estimate	V31 Costs	Future Costs
Planning & Design Total (Schedule A)	**$ 90,000**	**$ 90,000**	**$ 0**
Construction Total (Schedule B)	**$ 14,524,429**	**$ 10,608,000**	**$ 3,916,429**
Post Construction Total (Schedule C)	**$ 477,000**	**$ 348,380**	**$ 128,620**
Contingencies, 10% (Schedules A, B, & C)	**$ 1,509,143**	**$ 1,104,638**	**$ 404,505**
Subtotal	**$ 16,600,572**	**$ 12,151,018**	**$ 4,449,554**
TERO/Tribal Tax, 3.0%	**$ 498,017**	**$ 364,531**	**$ 133,487**
Tribal Administrative Support Fee*	**$ 336,511**	**$ 245,270**	**$ 91,241**
Tribal Fees	**$ 834,529**	**$ 609,801**	**$ 224,728**
IHS Engineering Program Support, 10% (EPS)	**$ 260,379**	**$ 260,379**	
IHS Project Technical Support Fee, 8% (PTS)	**$ 1,328,046**	**$ 972,081**	**$ 355,964**
Total Cost	**$ 19,023,525**	**$ 13,993,279**	**$ 5,030,246**
Use Total Cost of	**$ 19,024,000**	**$ 13,993,000**	**$ 5,030,000**
IHS Funded		**$ 11,000,000**	
EPA FY 18 Commitment		**$ 3,000,000**	
U62 EPA Funding			**$ 985,000**
Shortfall			**$ 4,045,000**
NTUA Power Line Extension (by Tribe/HUC)	**$ 1,100,000**		

UPDATED 2019 "HYBRID" COST ESTIMATE

Schedule A: Planning and Design

Item	Description	Qty	Units	Unit Cost	Total
1	Geotechnical Investigations	1	LS	$ 75,000	$ 75,000
2	Archaeological Survey and Monitoring	1	LS	$ 15,000	$ 15,000
				Pre-Construction Total:	**$ 90,000**

Schedule B: Construction

Item	Description	Qty	Units	Unit Cost	Total
	Power, Generators				
3	200 KW Mobile Generator (Wells)	1	EA	$ 125,000	$ 125,000
4	100 KW Mobile Generator (Booster Sta)	1	EA	$ 75,000	$ 75,000
5	Power Extension (Booster 1)	1	EA	$ 804,000	$ 804,000
6	Power Extension (Booster 2)	1	EA	$ 100,000	$ 100,000
	Water Mains, Gate Valves, ARVs, PRVs				
7	SWPPP	1	LS	$ 32,400	$ 32,400
8	12" HDPE, SDR 9 IPS	25,359	LF	$ 58.00	$ 1,470,822
9	12" HDPE, SDR 11 IPS	27,699	LF	$ 53.00	$ 1,468,047
10	12" HDPE, SDR 13.5 IPS	15,820	LF	$ 48.00	$ 759,360
11	10" HDPE, SDR 11 DIPS	5,255	LF	$ 42.00	$ 220,710
12	10" HDPE, SDR 13.5 IPS	32,484	LF	$ 39.00	$ 1,266,876
13	8" HDPE, SDR 9 DIPS	7,775	LF	$ 33.00	$ 256,575
14	8" HDPE, SDR 11 IPS	11,389	LF	$ 30.00	$ 341,670
15	8" HDPE, SDR 13.5 IPS	73,317	LF	$ 28.00	$ 2,052,876
16	8" C900 PVC DR 25	5,569	LF	$ 39.00	$ 217,191
17	6" HDPE, SDR 9 IPS	442	LF	$ 30.00	$ 13,260
18	6" HDPE, SDR 11 IPS	183	LF	$ 28.00	$ 5,124
19	6" HDPE, SDR 13.5 IPS	7,273	LF	$ 26.00	$ 189,098
20	4" HDPE SDR 13.5 IPS	5,073	LF	$ 22.00	$ 111,606
21	Rock Excavation	60,000	LF	$ 21.00	$ 1,260,000
22	12" Gate Valves	16	EA	$ 3,500	$ 56,000
23	10" Gate Valves	10	EA	$ 3,000	$ 30,000
24	8" Gate Valves	22	EA	$ 2,250	$ 49,500
25	6" Gate Valves	6	EA	$ 2,000	$ 12,000
26	4" Gate Valves	4	EA	$ 1,800	$ 7,200
27	Flush Valve	19	EA	$ 8,000	$ 152,000
28	Pressure Reducing Valve & Vault	1	EA	$ 20,000	$ 20,000
29	Air Relief Valves	35	EA	$ 5,000	$ 175,000
	Pumps and Motors				
30	100 hp Submersible Well Pump (385S1000-12), Drop Pipe, Building, Piping, Meter	2	EA	$ 210,000	$ 420,000
31	20 hp Booster Station CR45-3-2, Piping, Meter	1	EA	$ 130,000	$ 130,000
32	5 hp Booster Station CR20-2, Piping, Meter	1	EA	$ 100,000	$ 100,000
	Tank Level Control and Connections				
33	Altitude Valve & Vault	2	EA	$ 35,000	$ 70,000
34	Solenoid Valve & Vault	1	EA	$ 20,000	$ 20,000
35	Master Meter	6	EA	$ 10,000	$ 60,000
36	Existing Tank Interconnection	2	EA	$ 10,000	$ 20,000
37	Electrical/Telemetry	4	EA	$ 200,000	$ 800,000
	Disinfection Facilities				
38	HAMP Disinfection Facility	2	EA	$ 30,000	$ 60,000
	Wash Crossing				
39	Directional Bore - Wepo Wash (3x)	1,500	LF	$ 180	$ 270,000
	Road Excavation and Repair				
40	Road Excavation and Repair - Unpaved Open Cut	2,250	LF	$ 250	$ 562,500
41	Road Excavation and Repair - Paved Open Cut	400	LF	$ 300	$ 120,000
42	Paved Road Crossing - Jack & Bore	1,800	LF	$ 200	$ 360,000

Item	Description	Qty	Units	Unit Cost	Total
	Water Storage Tanks				
43	310,000 gallon Hopi Tank #1 Route 8, 24' H x 48' D	1	LS	$ 750,000	$ 750,000
44	110,000 gallon Hopi Tank #2 West Tank, 24' H x 48' D	1	LS	$ 375,000	$ 375,000
45	92,000 gallon Hopi Tank #3, at Route 17, 55' H x 17' D	1	LS	$ 325,000	$ 325,000
				Construction Total:	**$ 15,713,815**

Schedule C: Post Construction

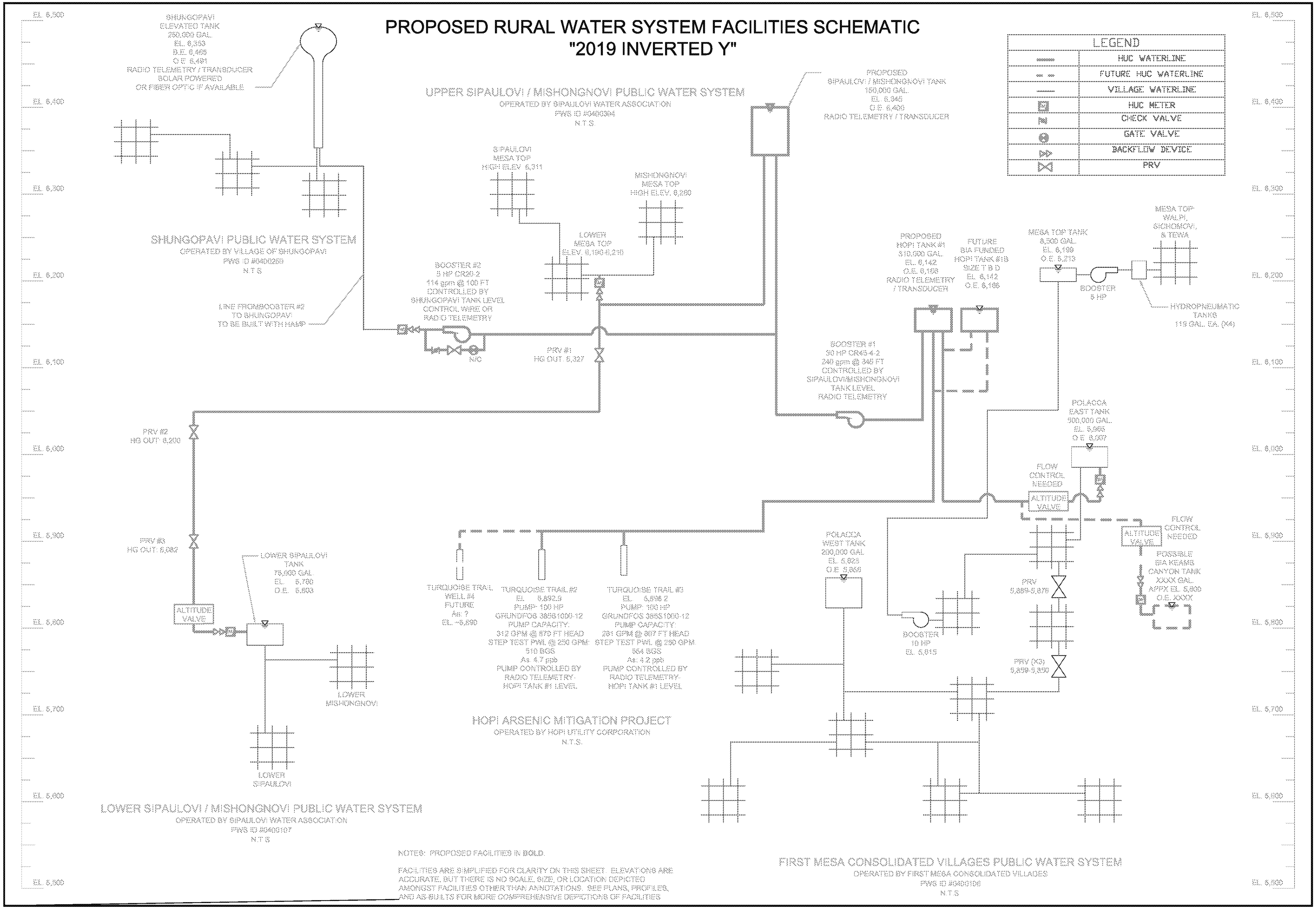
Item	Description	Qty	Units	Unit Cost	Total
46	1-Year Start-Up Assistance	24	DAYS	$ 500	$ 12,000
47	O&M Materials, Equipment and Space	1	LS	$ 425,000	$ 425,000
48	O&M Manual Development	1	LS	$ 40,000	$ 40,000
				Post Construction Total:	**$ 477,000**

	Total Cost Estimate	V31 Costs	Future Costs
Planning & Design Total (Schedule A)	**$ 90,000**	**$ 90,000**	**$ 0**
Construction Total (Schedule B)	**$ 15,713,815**	**$ 10,608,000**	**$ 5,105,815**
Post Construction Total (Schedule C)	**$ 477,000**	**$ 322,011**	**$ 154,989**
Contingencies, 10% (Schedules A, B, & C)	**$ 1,628,082**	**$ 1,102,001**	**$ 526,080**
Subtotal	**$ 17,908,897**	**$ 12,122,012**	**$ 5,786,885**
TERO/Tribal Tax, 3.0%	**$ 537,267**	**$ 363,660**	**$ 173,607**
Tribal Administrative Support Fee*	**$ 362,678**	**$ 244,690**	**$ 117,988**
Tribal Fees	**$ 899,945**	**$ 608,351**	**$ 291,594**
IHS Engineering Program Support, 10% (EPS)	**$ 259,757**	**$ 259,757**	
IHS Project Technical Support Fee, 8% (PTS)	**$ 1,432,712**	**$ 969,761**	**$ 462,951**
Total Cost	**$ 20,501,310**	**$ 13,959,881**	**$ 6,541,430**
Use Total Cost of	**$ 20,501,000**	**$ 13,960,000**	**$ 6,541,000**
IHS Funded		**$ 11,000,000**	
EPA FY 18 Commitment		**$ 3,000,000**	
U62 EPA Funding			**$ 985,000**
Shortfall			**$ 5,556,000**
NTUA Power Line Extension (by Tribe/HUC)	**$ 1,100,000**		

Appendix B

Alternatives Schematics

PROPOSED RURAL WATER SYSTEM FACILITIES SCHEMATIC
"2019 INVERTED Y"



NOTES: PROPOSED FACILITIES IN BOLD.

FACILITIES ARE SIMPLIFIED FOR CLARITY ON THIS SHEET. ELEVATIONS ARE ACCURATE, BUT THERE IS NO SCALE, SIZE, OR LOCATION DEPICTED AMONGST FACILITIES OTHER THAN ANNOTATIONS. SEE PLANS, PROFILES, AND AS-BUILTS FOR MORE COMPREHENSIVE DEPICTIONS OF FACILITIES

DATE | REVISIONS | INIT.

INDIAN HEALTH SERVICE
OFFICE OF ENVIRONMENTAL HEALTH & ENGINEERING
HOPI HEALTH CARE CENTER
P.O. BOX 4000
POLACCA, AZ 86042
(928) 737-6000

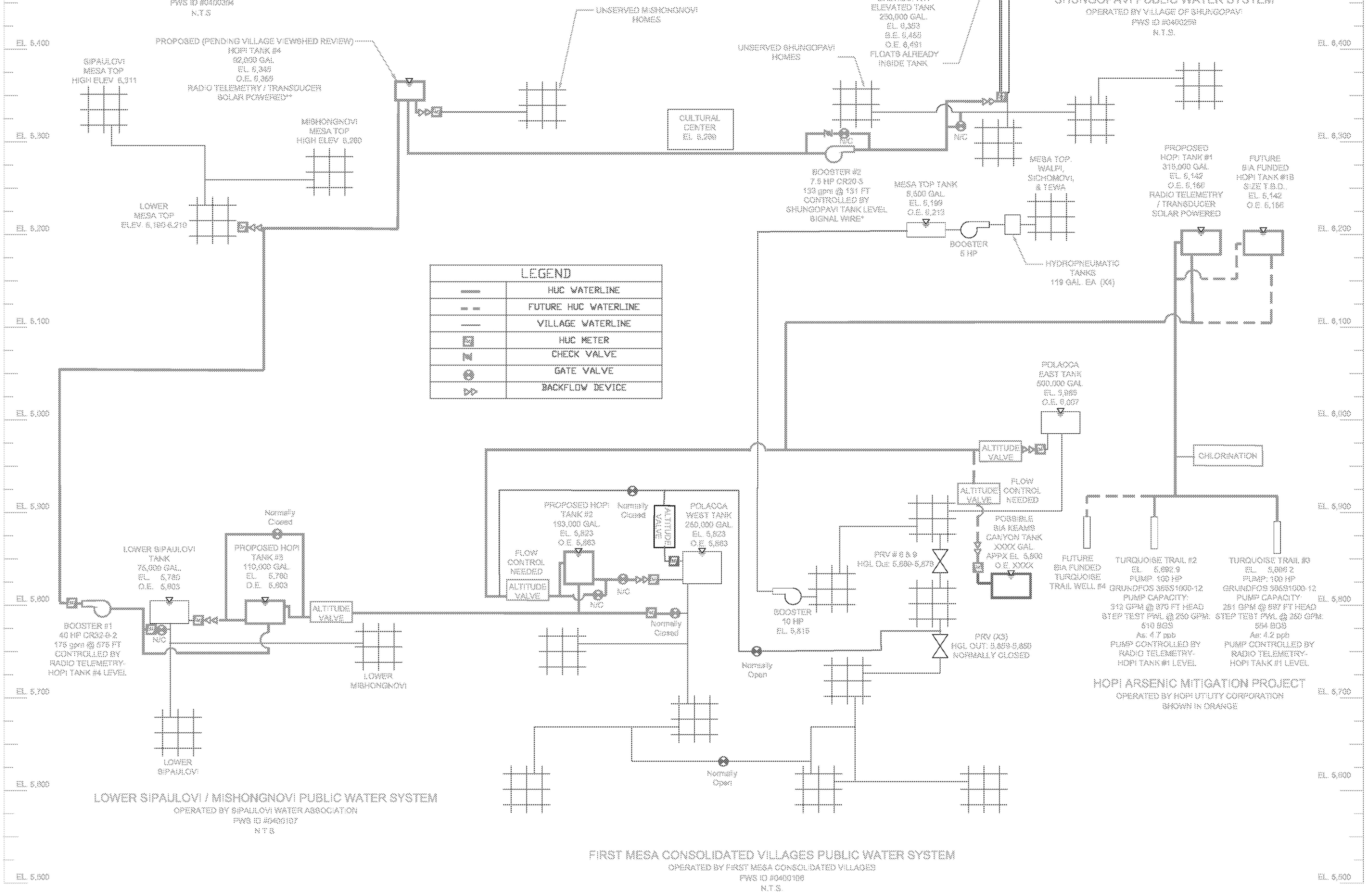
INDIAN HEALTH SERVICE 1955

THE HOPI TRIBE
HOPI RESERVATION - NAVAJO COUNTY, ARIZONA
HOPI ARSENIC MITIGATION PROJECT
PROPOSED FACILITIES SCHEMATIC "INVERTED Y"
PH 18-V31

RA NUMBER: ------ | SCALE: AS NOTED | FILE NAME: HAMP-S-STRUCTURE 10K
DRAWN BY: JVV | DATE: 04/2019 | LAYOUT NAME: INVERT Y
CHECKED BY: JC | DATE: 05/2019 | PROJ ENG: JOSHUA VAN VLEET

Invert Y
SHEET 1 OF 3

PROPOSED RURAL WATER SYSTEM FACILITIES SCHEMATIC
"J-Hook"



LEGEND	
——	HUC WATERLINE
— —	FUTURE HUC WATERLINE
——	VILLAGE WATERLINE
⊡	HUC METER
⋈	CHECK VALVE
⊗	GATE VALVE
▷▷	BACKFLOW DEVICE

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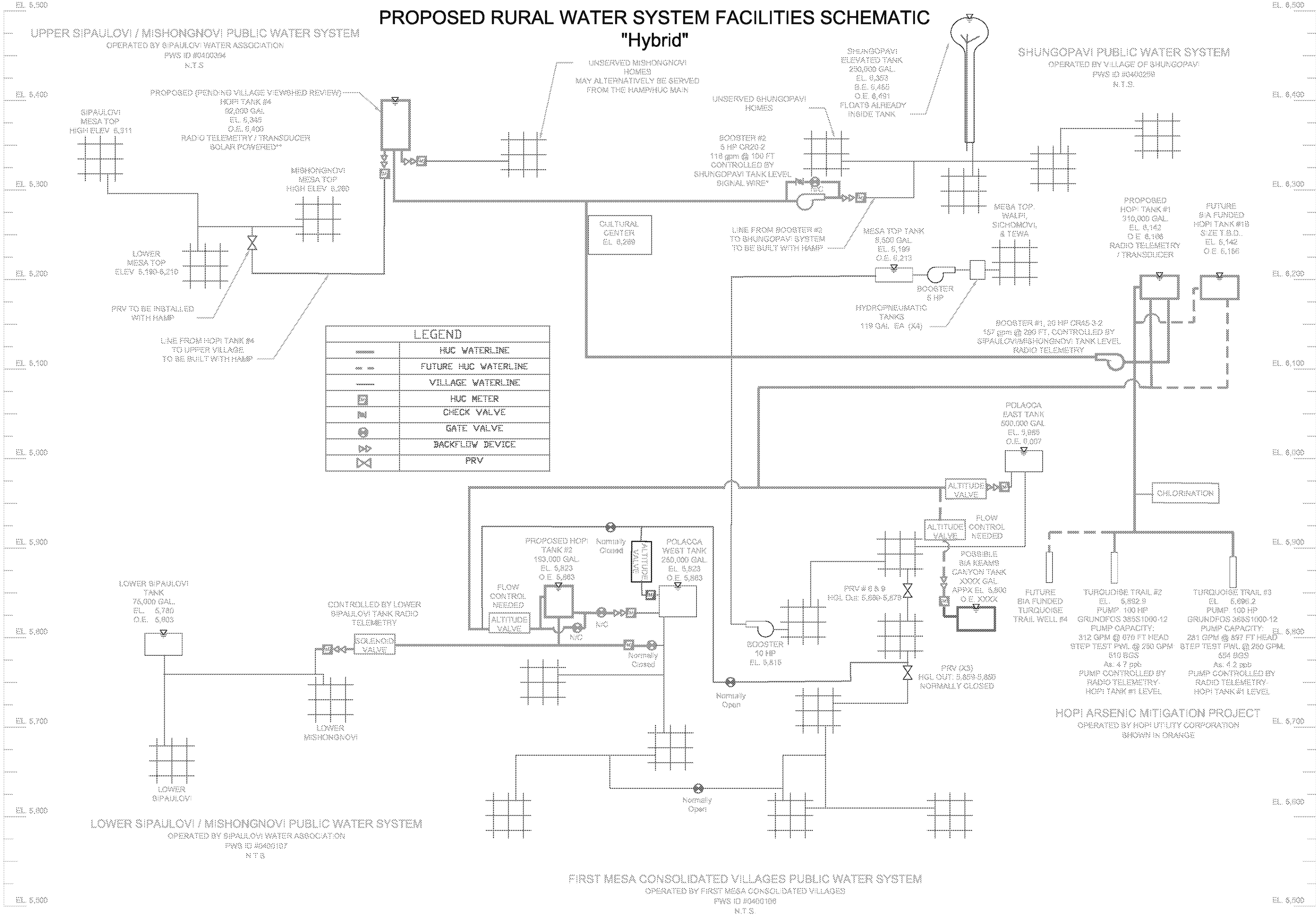
(928) 737-6000

THE HOPI TRIBE
HOPI RESERVATION - NAVAJO COUNTY, ARIZONA
HOPI ARSENIC MITIGATION PROJECT
PROPOSED FACILITIES SCHEMATIC "J-HOOK"
PH 18-V31

SHEET 2 OF 3

PROPOSED RURAL WATER SYSTEM FACILITIES SCHEMATIC
"Hybrid"



LEGEND

——	HUC WATERLINE
— —	FUTURE HUC WATERLINE
——	VILLAGE WATERLINE
⊡	HUC METER
⋈	CHECK VALVE
⊗	GATE VALVE
▷▷	BACKFLOW DEVICE
⋈	PRV

DATE | REVISIONS | INIT.

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INDIAN HEALTH SERVICE 1955

THE HOPI TRIBE
HOPI RESERVATION - NAVAJO COUNTY, ARIZONA
HOPI ARSENIC MITIGATION PROJECT
PROPOSED FACILITIES SCHEMATIC "HYBRID"
PH 18-V31

SHEET 3 OF 3

Appendix C

Present Worth Life Cycle Calculation Sheet

Project	HOPI HAMP			HAMP "Inverted-Y"	HAMP "J-Hook"	HAMP "Hybrd"
Life Cycle Period		20 years				
OMB A-94 Real Interest Rate	0.20%	Escalation Rate	0.00%		Note: Highted Cells	Enter manually

http://www.whitehouse.gov/omb/circulars_a094/a94_appx-c

A. Initial Cost (Capital Cost)

	HAMP "Inverted-Y"	HAMP "J-Hook"	HAMP "Hybrd"
1. Construction	$16,221,219	$14,949,429	$16,138,815
2. Non-Construction	$4,382,781	$4,074,571	$4,362,185
Total Initial Costs	**$20,604,000**	**$19,024,000**	**$20,501,000**

B. Operations and Maintenance (O&M)

	Reduced $54k due to savings in each village O&M	Reduced $54k due to savings in each village O&M	Reduced $54k due to savings in each village O&M
O&M (does not include debt or replacements-SLA)	$315,000	$315,000	$315,000
Total Annual Costs	$315,000	$315,000	$315,000
Present Worth Factor	19.5861	19.5861	19.5861
Present Worth of RECURRENT COSTS	**$6,170,000**	**$6,170,000**	**$6,170,000**

C. Replacement Reserve - Short Lived Assets (SLA)

	Years	20	20	20
Short Lived Assets (SLA)	Total Cost for Replacements/Repair	$1,606,160	$1,648,000	$1,606,460
(use avg yearly SLA calculation w/o escalation)	Yearly Cost	$80,308	$82,400	$80,323
	Present Worth Factor	19.5861	19.5861	19.5861
	Present Worth of REPLACEMENTS	**$1,573,000**	**$1,614,000**	**$1,573,000**

D. Salvage Value

NOTES	Assume most of Construction @ 60 year Life, except Pumps & Disinfection. Need to include well drilling cost.	Assume most of Construction @ 60 year Life, except Pumps & Disinfection. Need to include well drilling cost.	Assume most of Construction @ 60 year Life, except Pumps & Disinfection. Need to include well drilling cost.
Useful Life (years)	60	60	60
Construction Cost - Waterlines, Tanks, Powerlines	$15,496,219	$14,224,429	$15,438,815
Salvage Value (assume straight-line of construction cost)	$10,330,813	$9,482,953	$10,292,543
Useful Life (years)	40	40	40
Construction Cost - Well Drilling/Casing	$0	$0	$0
Salvage Value (assume straight-line of construction cost)	$0	$0	$0
Useful Life (years)	25	25	25
Construction Cost - Treatment System, Disinfection, Generators & Pumps	$725,000	$725,000	$700,000
Salvage Value (assume straight-line of construction cost)	$145,000	$145,000	$140,000
TOTAL CONSTRUCTION COST	$16,221,219	$14,949,429	$16,138,815
TOTAL SALVAGE VALUE	$10,475,813	$9,627,953	$10,432,543
Present Worth Factor	0.9608	0.9608	0.9608
Present Worth of SALVAGE VALUE	**$10,065,000**	**$9,251,000**	**$10,024,000**

LIFE CYCLE - PRESENT WORTH SUMMARY

A. Capital Cost	$20,604,000	$19,024,000	$20,501,000
B. Annual O&M (PRESENT WORTH)	$6,170,000	$6,170,000	$6,170,000
C. Annual SLA (PRESENT WORTH)	$1,573,000	$1,614,000	$1,573,000
D. Salvage Value (PRESENT WORTH)	$10,065,000	$9,251,000	$10,024,000
G. TOTAL PRESENT WORTH COST (A+B+C-D)	**$18,282,000**	**$17,557,000**	**$18,220,000**
FINAL PW COSTS		Least Expensive	

Appendix D

Repair and Replace Worksheets

HAMP R&R PRESENT VALUE 4/19/19
Updated Inverted-Y
Life Cycle, years 20
Does not include replacement in last year of life cycle
Includes rehab in last year of life cycle for assets with RUL longer than last year of life cycle
Inflation 0.02 0.02
Fund interest 0.002 0.002

	Quantity	Replace Life3 (years)	Rehab Interval (years)	Replace Cost each	Rehab Cost each	No. of Replace	2018 Annual Replace	No. of Rehabs	Sum of 20 yr Annual Rehab
Wells									
Well Pump/Motor	2	20	10 20	$ 45,000	$ 10,000	0	6560.60	1	3874.04
Casing&Screens	2	40	15	$ 500,000	$ 10,000	0	53077.54	1	1602.01
Pump Column	2	30	10 20	$ 13,000	$ 5,000	0	1524.79	2	1937.02
Valves - 8"	4	30	10 20	$ 1,500	$ 500	0	351.87	2	387.40
Well Buildings									
Structure	2	40	15	$ 40,000	$ 3,000	0	4246.20	1	530.85
VFD/PLC/Telemetry6	2	15	0	$ 40,000	$ -	1	7078.01	0	
Electrical Equip	2	30	10 20	$ 35,000	$ 5,000	0	4105.21	2	1937.02
Diesel Mobile Generator (150kw)	1	25	5 10 15 20	$ 90,000	$ 3,000	0	5765.66	4	1506.34
HVAC	1	20	5 10 15 20	$ 5,000	$ 500	0	364.48	3	251.06
Surge Tank	1	40	10 20	$ 10,000	$ 1,000	0	530.78	2	193.70
Surge Air System	1	20	10 20	$ 8,000	$ 1,000	0	583.16	1	193.70
Chlorination System	1	20	5 10 15 20	$ 5,000	$ 500	0	364.48	3	251.06
Booster Station 1									
Structure	1	40	15	$ 40,000	$ 3,000	0	2123.10	1	265.43
Pumps - Duplex Pack	1	20	10 20	$ 37,000	$ 2,000	0	2697.14	1	387.40
Yard Piping and Valves (5) 8" Valves	1	40	10 20	$ 30,000	$ 1,000	0	1592.33	2	193.70
VFD/PLC/Telemetry6	1	15	0	$ 60,000	$ -	1	5308.51	0	
Electrical Equip	1	30	10 20	$ 30,000	$ 3,000	0	1759.37	2	581.11
Diesel Mobile Generator (150KW)	1	25	5 10 15 20	$ 90,000	$ 3,000	0	5765.66	4	1506.34
Surge Tank	1	40	10 20	$ 8,000	$ 1,000	0	424.62	2	193.70
Surge Air System	1	20	10 20	$ 5,000	$ 1,000	0	364.48	1	193.70
Storage Tank									

	Quantity	Replace Life3 (years)	Rehab Interval (years)	Replace Cost each	Rehab Cost each	No. of Replace	2018 Annual Replace	No. of Rehabs	Sum of 20 yr Annual Rehab
Hopi Tank 1, 315,000 gal	1	40	20	$ 600,000	$ 30,000	0	31846.53	1	2186.87
Piping & Valves (500 ft 8-inch)	1	40	10 20	$ 35,000	$ 1,000	0	1857.71	2	193.70
Telemetry/Controls	1	15	0	$ 30,000	$ -	1	2654.25	0	
Transmission Pipelines									
12" PVC Pipe	68,878	75	0	$ 53	$ -	0	199432.59	0	
10" Pipe	60,743	75	0	$ 39	$ -	0	129419.76	0	
8" Pipe	62,895	75	0	$ 35	$ -	0	120260.75	0	
4" & 6" Pipe	13,751	75	0	$ 30	$ -	0	22536.96	0	
12" Isolation Valves	16	30	15	$ 4,000	$ 500	0	3753.33	1	707.80
10" Isolation Valves	14	30	15	$ 3,000	$ 500	0	2463.12	1	619.33
8" Isolation Valves	18	30	15	$ 2,250	$ 500	0	2375.16	1	796.28
4" & 6" Isolation Valves	12	30	15	$ 2,000	$ 500	0	1407.50	1	530.85
Air Release	30	20	5 10 15 20	$ 5,000	$ 500	0	10934.34	3	7531.68
Flush Valve	19	30	15	$ 8,000	$ 500		8914.16		840.51
Pressure Reducing Valve	3	25	5 10 15 20	$ 20,000	$ 500		3843.77		753.17
Paved Roadway 1950 ft	1	20	10	$ 39,150	$ 12,000	0	2853.86	1	1449.68
Village Connections									
Flowmeter& Vault	6	25	10 20	$ 5,000	$ 1,000	0	1921.89	2	1162.21
Backflow Preventer	3	25	10 20	$ 3,000	$ 500	0	576.57	2	290.55
Chlorination Facility	1	15	5 10 15 20	$ 30,000	$ 1,000	1	2654.25	3	502.11
Altitude Valves FMCV East Tank	1	25	10 20	$ 10,000	$ 1,000	0	640.63	2	193.70
Sipaulovi/Mishongnovi Tank									
Tank, 150,000 gal	1	40	20	$ 480,000	$ 15,000	0	25477.22	1	1093.43
Yard Piping and valves (5) 8" Valves	1	40	10 20	$ 35,000	$ 1,000	0	1857.71	2	193.70
Controls	1	15	0	$ 40,000	$ -	1	3539.00	0	
Booster Station 2									
Structure	1	40	15	$ 40,000	$ 3,000	0	2123.10	1	265.43
Pumps - Duplex Pack	1	20	10 20	$ 30,000	$ 2,000	0	2186.87	1	387.40
4" Valves	8	30	15	$ 1,500	$ 500	0	703.75	1	1415.60
VFD/PLC/Telemetry6	1	15	0	$ 40,000	$ -	1	3539.00	0	

	Quantity	Replace Life3 (years)	Rehab Interval (years)	Replace Cost each	Rehab Cost each	No. of Replace	2018 Annual Replace	No. of Rehabs	Sum of 20 yr Annual Rehab
Electrical Equip	1	30	10 20	$ 30,000	$ 3,000	0	1759.37	2	581.11
Storage/Admin Building									
Structure	1	40	15	$ 75,000	$ 3,000	0	3980.82	1	265.43
Hoist	1	30	10 20	$ 10,000	$ 500	0	586.46	2	96.85
HVAC	1	20	5 10 15 20	$ 10,000	$ 1,000	0	728.96	3	502.11
Vehicles									
Service Truck	1	6 12 18	3 6 9 12 15 18	$ 30,000	$ 1,000	3	10384.00	3	942.53
ATV	1	6 12 18	3 6 9 12 15 18	$ 15,000	$ 500	3	5192.00	3	471.26
							$ 716,993		
Totals							$ 40,349		39958.85

HAMP R&R PRESENT VALUE 4/19/19
Updated J-Hook

Life Cycle, years	20	
Does not include replacement in last year of life cycle		
Includes rehab in last year of life cycle for assets with RUL longer than last year of life cycle		
Inflation	0.02	0.02
Fund interest	0.002	0.002

	Quantity	Replace Life3 (years)	Rehab Interval (years)	Replace Cost each	Rehab Cost each	2018 Annual Replace	No. of Rehabs	Sum of 20 yr Annual Rehab
Wells								
Well Pump/Motor	2	20	10 20	$ 35,000	$ 10,000	5102.69	1	3874.04
Casing&Screens	2	40	15	$ 500,000	$ 10,000	53077.54	1	1602.01
Pump Column	2	30	10 20	$ 13,000	$ 5,000	1524.79	2	1937.02
Valves - 8"	4	30	10 20	$ 1,500	$ 500	351.87	2	387.40
Well Buildings								
Structure	2	40	15	$ 40,000	$ 3,000	4246.20	1	530.85
VFD/PLC/Telemetry6	2	15	0	$ 40,000	$ -	7078.01	0	
Electrical Equip	2	30	10 20	$ 35,000	$ 5,000	4105.21	2	1937.02
Diesel Mobile Generator (150kw)	1	25	5 10 15 20	$ 90,000	$ 3,000	5765.66	4	1506.34
HVAC	1	20	5 10 15 20	$ 5,000	$ 500	364.48	3	251.06
Surge Tank	1	40	10 20	$ 10,000	$ 1,000	530.78	2	193.70
Surge Air System	1	20	10 20	$ 8,000	$ 1,000	583.16	1	193.70
Chlorination System	1	20	5 10 15 20	$ 5,000	$ 500	364.48	3	251.06
Storage Tank								
Hopi Tank 1, 315,000 gal	1	40	20	$ 600,000	$ 30,000	31846.53	1	2186.87
Piping & Valves (500 ft 8-inch)	1	40	10 20	$ 35,000	$ 1,000	1857.71	2	193.70
Telemetry/Controls	1	15	0	$ 30,000	$ -	2654.25	0	
Transmission Pipelines								
14" PVC Pipe	14,940	75	0	$ 53	$ -	43257.98	0	
12" PVC Pipe	86,386	75	0	$ 53	$ -	250126.07	0	
10" Pipe	17,735	75	0	$ 39	$ -	37786.40	0	
8" Pipe	51,807	75	0	$ 35	$ -	99059.52	0	

	Quantity	Replace Life3 (years)	Rehab Interval (years)	Replace Cost each	Rehab Cost each	2018 Annual Replace	No. of Rehabs	Sum of 20 yr Annual Rehab
4" & 6" Pipe	281	75	0	$ 30	$ -	460.54	0	
14" Isolation Valves	5	30	15	$ 5,000	$ 500	1466.15	1	221.19
12" Isolation Valves	20	30	15	$ 4,000	$ 500	4691.66	1	884.75
10" Isolation Valves	6	30	15	$ 3,000	$ 500	1055.62	1	265.43
8" Isolation Valves	14	30	15	$ 2,250	$ 500	1847.34	1	619.33
4" & 6" Isolation Valves	10	30	15	$ 2,000	$ 500	1172.92	1	442.38
Air Release	35	20	5 10 15 20	$ 5,000	$ 500	12756.73	3	8786.96
Flush Valve	15	30	15	$ 8,000	$ 500	7037.50		663.56
Paved Roadway 1950 ft	1	20	10	$ 39,150	$ 12,000	2853.86	1	1449.68
HUC Tank 2								
Hopi Tank 2, 193,000 gal	1	40	20	$ 510,000	$ 25,000	27069.55	1	1822.39
Yard Piping & Valves (8) 8-inch valve	1	40	10 20	$ 35,000	$ 1,000	1857.71	2	193.70
Altitude Valve	1	25	10 20	$ 10,000	$ 1,000	640.63	2	193.70
HUC Tank 3								
Hopi Tank 1, 110,000 gal	1	40	20	$ 360,000	$ 15,000	19107.92	1	1093.43
Yard Piping & Valves (8) 8-inch Valve)	1	40	10 20	$ 35,000	$ 1,000	1857.71	2	193.70
Altitude Valve	1	25	10 20	$ 10,000	$ 1,000	640.63	2	193.70
Village Connections								
Flowmeter& Vault	10	25	10 20	$ 5,000	$ 1,000	3203.14	2	1937.02
Backflow Preventer	3	25	10 20	$ 3,000	$ 500	576.57	2	290.55
Chlorination Facility	1	15	5 10 15 20	$ 30,000	$ 1,000	2654.25	3	502.11
Altitude Valves FMCV East Tank	1	25	10 20	$ 10,000	$ 1,000	640.63	2	193.70
Booster Station 1								
Structure	1	40	15	$ 40,000	$ 3,000	2123.10	1	265.43
Pumps - Duplex Pack	1	20	10 20	$ 50,000	$ 2,000	3644.78	1	387.40
Yard Piping and Valves (5) 8" Valves	1	40	10 20	$ 30,000	$ 1,000	1592.33	2	193.70
VFD/PLC/Telemetry6	1	15	0	$ 40,000	$ -	3539.00	0	
Electrical Equip	1	30	10	$ 30,000	$ 3,000	1759.37	2	581.11

	Quantity	Replace Life3 (years)	Rehab Interval (years)	Replace Cost each	Rehab Cost each	2018 Annual Replace	No. of Rehabs	Sum of 20 yr Annual Rehab
			20					
Diesel Mobile Generator (150KW)	1	25	5 10 15 20	$ 90,000	$ 3,000	5765.66	4	1506.34
Surge Tank	1	40	10 20	$ 8,000	$ 1,000	424.62	2	193.70
Surge Air System	1	20	10 20	$ 5,000	$ 1,000	364.48	1	193.70
Sipaulovi/Mishongnovi Tank								
Tank, 92,000 gal	1	40	20	$ 325,000	$ 15,000	17250.20	1	1093.43
Yard Piping and valves (5) 8" Valves	1	40	10 20	$ 35,000	$ 1,000	1857.71	2	193.70
Controls	1	15	0	$ 40,000	$ -	3539.00	0	
Booster Station 2								
Structure	1	40	15	$ 40,000	$ 3,000	2123.10	1	265.43
Pumps - Duplex Pack	1	20	10 20	$ 30,000	$ 2,000	2186.87	1	387.40
4" Valves	8	30	15	$ 1,500	$ 500	703.75	1	707.80
VFD/PLC/Telemetry6	1	15	0	$ 40,000	$ -	3539.00	0	
Electrical Equip	1	30	10 20	$ 30,000	$ 3,000	1759.37	2	581.11
Storage/Admin Building								
Structure	1	40	15	$ 75,000	$ 3,000	3980.82	1	265.43
Hoist	1	30	10 20	$ 10,000	$ 500	586.46	2	96.85
HVAC	1	20	5 10 15 20	$ 10,000	$ 1,000	728.96	3	502.11
Vehicles								
Service Truck	1	6 12 18	3 6 9 12 15 18	$ 30,000	$ 1,000	10384.00	3	942.53
ATV	1	6 12 18	3 6 9 12 15 18	$ 15,000	$ 500	5192.00	3	471.26
						$ 714,319		
Totals						$ 38,580		43820.47

HAMP R&R PRESENT VALUE 4/26/19
Updated Hybrid
Life Cycle, years 20
Does not include replacement in last year of life cycle
Includes rehab in last year of life cycle for assets with RUL longer than last year of life cycle
Inflation 0.02 0.02
Fund interest 0.002 0.002

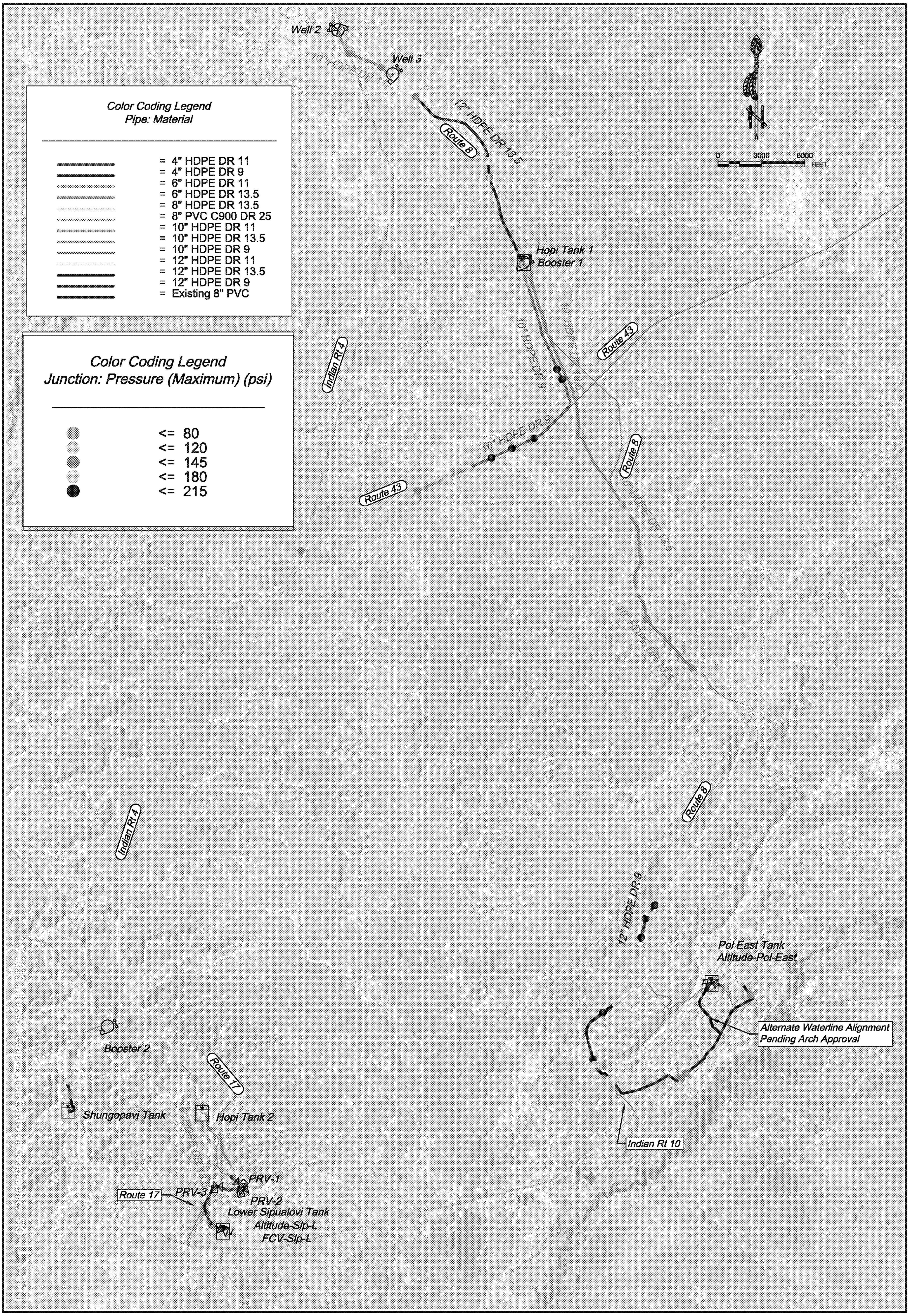
	Quantity	Replace Life3 (years)	Rehab Interval (years)	Replace Cost each	Rehab Cost each	2018 Annual Replace	No. of Rehabs	Sum of 20 yr Annual Rehab
Wells								
Well Pump/Motor	2	20	10 20	$ 35,000	$ 10,000	5102.69	1	3874.04
Casing&Screens	2	40	15	$ 500,000	$ 10,000	53077.54	1	1602.01
Pump Column	2	30	10 20	$ 13,000	$ 5,000	1524.79	2	1937.02
Valves - 8"	4	30	10 20	$ 1,500	$ 500	351.87	2	387.40
Well Buildings								
Structure	2	40	15	$ 40,000	$ 3,000	4246.20	1	530.85
VFD/PLC/Telemetry6	2	15	0	$ 40,000	$ -	7078.01	0	
Electrical Equip	2	30	10 20	$ 35,000	$ 5,000	4105.21	2	1937.02
Diesel Mobile Generator (150kw)	1	25	5 10 15 20	$ 90,000	$ 3,000	5765.66	4	1506.34
HVAC	1	20	5 10 15 20	$ 5,000	$ 500	364.48	3	251.06
Surge Tank	1	40	10 20	$ 10,000	$ 1,000	530.78	2	193.70
Surge Air System	1	20	10 20	$ 8,000	$ 1,000	583.16	1	193.70
Chlorination System	1	20	5 10 15 20	$ 5,000	$ 500	364.48	3	251.06
Storage Tank								
Hopi Tank 1, 315,000 gal	1	40	20	$ 600,000	$ 30,000	31846.53	1	2186.87
Piping & Valves (500 ft 8-inch)	1	40	10 20	$ 35,000	$ 1,000	1857.71	2	193.70
Telemetry/Controls	1	15	0	$ 30,000	$ -	2654.25	0	
Transmission Pipelines								
12" PVC Pipe	68,878	75	0	$ 53	$ -	199432.59	0	
10" Pipe	37,739	75	0	$ 39	$ -	80407.16	0	
8" Pipe	98,050	75	0	$ 35	$ -	187480.19	0	

	Quantity	Replace Life3 (years)	Rehab Interval (years)	Replace Cost each	Rehab Cost each	2018 Annual Replace	No. of Rehabs	Sum of 20 yr Annual Rehab
4" & 6" Pipe	12,971	75	0	$ 30	$ -	21258.59	0	
12" Isolation Valves	16	30	15	$ 4,000	$ 500	3753.33	1	707.80
10" Isolation Valves	10	30	15	$ 3,000	$ 500	1759.37	1	442.38
8" Isolation Valves	22	30	15	$ 2,250	$ 500	2902.97	1	973.23
4" & 6" Isolation Valves	10	30	15	$ 2,000	$ 500	1172.92	1	442.38
Air Release	35	20	5	$ 5,000	$ 500	12756.73	3	8786.96
			10					
			15					
			20					
Flush Valve	15	30	15	$ 8,000	$ 500	7037.50		663.56
Paved Roadway 1950 ft	1	20	10	$ 39,150	$ 12,000	2853.86	1	1449.68
Sipaulovi/Mishongnovi Tank (Tank 2)								
Tank, 92,000 gal	1	40	20	$ 325,000	$ 15,000	17250.20	1	1093.43
Yard Piping and valves (5) 8" Valves	1	40	10	$ 35,000	$ 1,000	1857.71	2	193.70
			20					
Controls	1	15	0	$ 40,000	$ -	3539.00	0	
			20					
HUC Tank 3								
Hopi Tank 3, 110,000 gal	1	40	20	$ 375,000	$ 15,000	19904.08	1	1093.43
Yard Piping & Valves (8) 8-inch Valve)	1	40	10	$ 35,000	$ 1,000	1857.71	2	193.70
			20					
Altitude Valve	1	25	10	$ 10,000	$ 1,000	640.63	2	193.70
			20					
Village Connections								
Flowmeter& Vault	10	25	10	$ 5,000	$ 1,000	3203.14	2	1937.02
			20					
Backflow Preventer	3	25	10	$ 3,000	$ 500	576.57	2	290.55
			20					
Chlorination Facility	1	15	5	$ 30,000	$ 1,000	2654.25	3	502.11
			10					
			15					
			20					
Altitude Valves FMCV East Tank	1	25	10	$ 10,000	$ 1,000	640.63	2	193.70
			20					
Booster Station 1								
Structure	1	40	15	$ 40,000	$ 3,000	2123.10	1	265.43
Pumps - Duplex Pack	1	20	10	$ 50,000	$ 2,000	3644.78	1	387.40
			20					
Yard Piping and Valves (5) 8" Valves	1	40	10	$ 30,000	$ 1,000	1592.33	2	193.70
			20					
VFD/PLC/Telemetry6	1	15	0	$ 40,000	$ -	3539.00	0	
Electrical Equip	1	30	10	$ 30,000	$ 3,000	1759.37	2	581.11
			20					
Diesel Mobile Generator (150KW)	1	25	5	$ 90,000	$ 3,000	5765.66	4	1506.34

	Quantity	Replace Life3 (years)	Rehab Interval (years)	Replace Cost each	Rehab Cost each	2018 Annual Replace	No. of Rehabs	Sum of 20 yr Annual Rehab
			10					
			15					
			20					
Surge Tank	1	40	10	$ 8,000	$ 1,000	424.62	2	193.70
			20					
Surge Air System	1	20	10	$ 5,000	$ 1,000	364.48	1	193.70
			20					
Booster Station 2								
Structure	1	40	15	$ 40,000	$ 3,000	2123.10	1	265.43
Pumps - Duplex Pack	1	20	10	$ 30,000	$ 2,000	2186.87	1	387.40
			20					
4" Valves	8	30	15	$ 1,500	$ 500	703.75	1	707.80
VFD/PLC/Telemetry6	1	15	0	$ 40,000	$ -	3539.00	0	
Electrical Equip	1	30	10	$ 30,000	$ 3,000	1759.37	2	581.11
			20					
Storage/Admin Building								
Structure	1	40	15	$ 75,000	$ 3,000	3980.82	1	265.43
Hoist	1	30	10	$ 10,000	$ 500	586.46	2	96.85
			20					
HVAC	1	20	5	$ 10,000	$ 1,000	728.96	3	502.11
			10					
			15					
			20					
Vehicles								
Service Truck	1	6	3	$ 30,000	$ 1,000	10384.00	3	942.53
		12	6					
		18	9					
			12					
			15					
			18					
ATV	1	6	3	$ 15,000	$ 500	5192.00	3	471.26
		12	6					
		18	9					
			12					
			15					
			18					
						$ 742,790		
Totals						$ 38,580		41743.38

Appendix E

Water Model Results



SHEET 04 OF 06

Y Press

THE HOPI TRIBE
NAVAJO COUNTY, ARIZONA
Hopi Arsenic Mitigation Regional Waterline Project
Alternative inverted Y: Max Pressure in Water Model
PH 18-V31

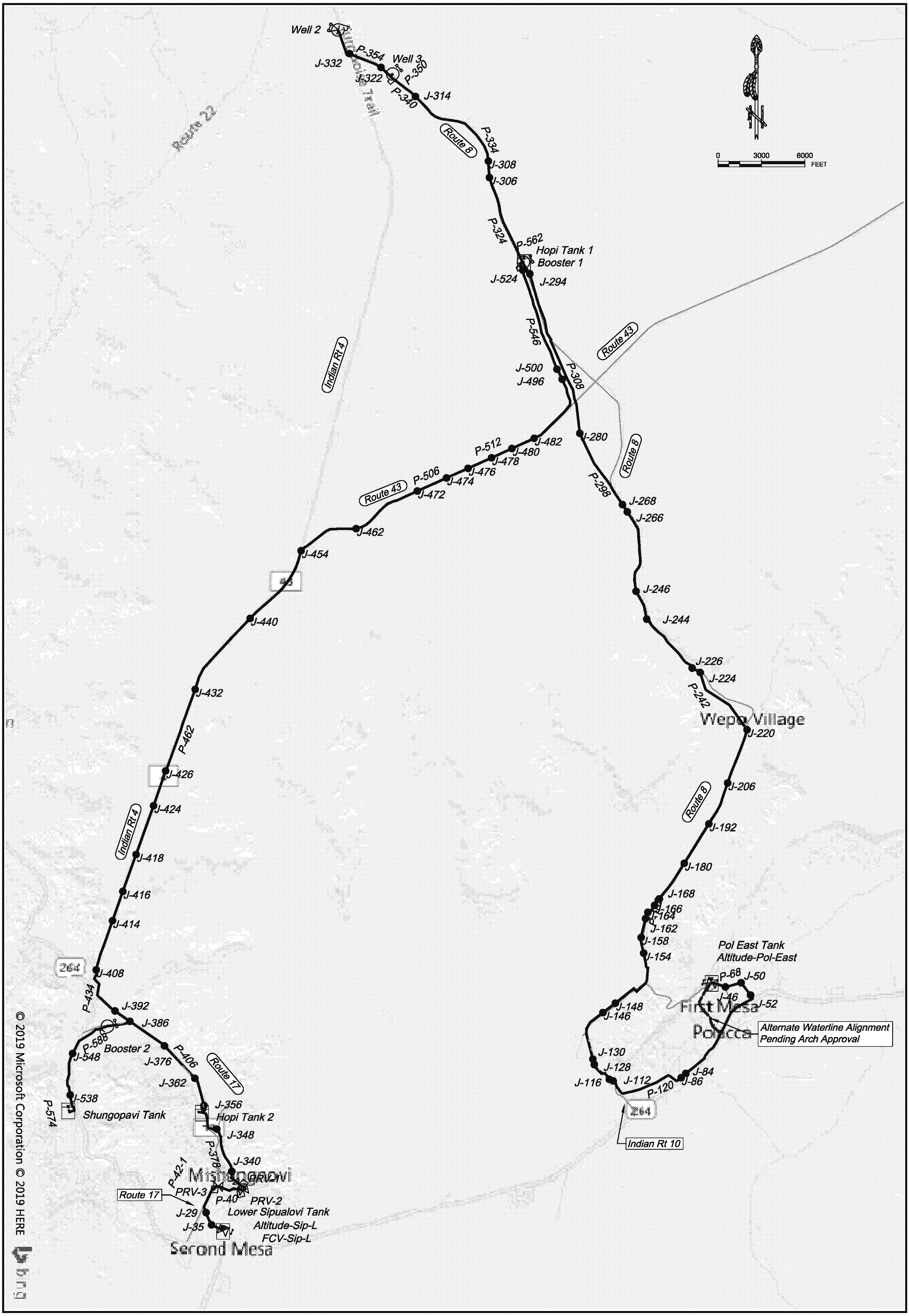
DRAWN BY: JPC	DATE: 4-9-19	FILE NAME: INVERTED Y
CHECKED BY: JVV/BB	DATE:	WA NUMBER: ....
APPROVED BY:	DATE:	PROJ ENG: ....

INDIAN HEALTH SERVICE
OFFICE OF ENVIRONMENTAL
HEALTH & ENGINEERING

HOPI HEALTH CARE CENTER
P.O. BOX 4000
POLACCA, AZ 86042
(928) 737-6000

DATE	REVISIONS	INT.

ED_005149_00041585-00056



THE HOPI TRIBE NAVAJO COUNTY, ARIZONA Hopi Arsenic Mitigation Regional Water Project Alternative Inverted Y: IDs in Water Model PH 18-V31		INDIAN HEALTH SERVICE OFFICE OF ENVIRONMENTAL HEALTH & ENGINEERING
DRAWN BY: FPC / DATE: 4-4-19	FILE NAME: INVERTED Y	HOPI HEALTH CARE CENTER P.O. BOX 4000 POLACCA, AZ 86042 (928) 737-6000
CHECKED BY: JVV/BR / DATE:	RA NUMBER:	
APPROVED BY: .... / DATE:	PROJ ENG:	

Y Model ID

SHEET 03 OF 06

INDIAN HEALTH SERVICE 1955

DATE	REVISIONS	INIT.

Hopi Regional Water System
FlexTable: Junction Table
Active Scenario: Inverted Y 2057
Current Time: 0.25 hours

Label	Elevation (ft)	Pressure (Maximum) (psi)	Pressure (Minimum) (psi)
J-340	6,185.00	93	86
J-348	6,190.00	91	85
J-306	6,000.00	76	70
J-414	6,235.00	83	65
J-35	5,765.00	136	122
J-224	5,829.00	145	110
J-154	5,777.00	168	119
J-148	5,770.00	171	119
J-226	5,847.00	138	103
J-332	5,893.84	131	116
J-314	5,905.00	122	111
J-408	6,294.95	55	39
J-308	5,981.00	85	78
J-322	5,880.00	136	122
J-548	6,329.30	70	67
J-538	6,327.73	70	68
J-392	6,313.48	44	31
J-386	6,310.75	44	32
J-376	6,304.83	45	35
J-362	6,332.48	31	24
J-356	6,347.51	23	18
J-158	5,747.60	181	132
J-162	5,740.34	184	136
J-164	5,749.09	180	133
J-166	5,748.73	180	133
J-168	5,751.47	179	133
J-180	5,770.91	171	126
J-192	5,773.42	169	127
J-206	5,782.85	165	124
J-220	5,787.79	163	124
J-244	5,882.87	122	92
J-246	5,893.72	117	89
J-266	5,977.03	81	59
J-268	5,998.56	72	51
J-50	5,760.10	175	107
J-46	5,875.43	125	57
J-146	5,730.11	188	135
J-130	5,734.27	186	131
J-128	5,756.54	177	121
J-116	5,750.63	179	122
J-112	5,733.56	187	129
J-84	5,688.85	206	144
J-86	5,686.96	207	145

Hopi Regional Water System
FlexTable: Junction Table
Active Scenario: Inverted Y 2057

Current Time: 0.25 hours

Label	Elevation (ft)	Pressure (Maximum) (psi)	Pressure (Minimum) (psi)
J-52	5,715.15	195	127
J-480	6,033.85	202	152
J-478	6,052.72	193	144
J-476	6,110.23	167	119
J-474	6,151.48	149	101
J-472	6,174.29	138	91
J-462	6,218.57	116	72
J-454	6,191.71	124	84
J-440	6,212.33	111	75
J-432	6,195.92	113	82
J-426	6,221.10	98	71
J-424	6,255.18	81	56
J-418	6,269.55	72	50
J-416	6,225.43	89	69
J-294	6,121.96	19	15
J-280	6,023.32	61	46
J-482	6,018.43	209	159
J-500	6,040.84	202	149
J-496	6,033.78	205	152
J-524	6,125.52	168	112
J-29	5,773.00	131	122

Hopi Regional Water System
FlexTable: Pipe Table
Active Scenario: Inverted Y 2057
Current Time: 0.25 hours

Label	Length (3D) (ft)	Start Node	Stop Node	Diameter (in)	Material	C Factor	Flow (gpm)	Velocity (ft/s)	Headloss Gradient (ft/ft)	Headloss (ft)
P-340	2,215	J-316	J-314	10.290	12" HDPE DR 11	140.0	627	2.42	0.002	4.26
P-334	2,101	J-310	J-308	10.750	12" HDPE DR 13.5	140.0	627	2.21	0.002	3.27
P-324	3,195	J-300	J-298	10.750	12" HDPE DR 13.5	140.0	627	2.21	0.002	4.97
P-40	1,787	J-32	J-121	3.633	4" HDPE DR 11	140.0	75	2.32	0.006	10.98
P-354	885	J-328	J-324	8.679	10" HDPE DR 11	140.0	322	1.74	0.001	1.16
P-588	1,041	J-552	J-550	8.280	8" PVC C900 DR 25	140.0	119	0.71	0.000	0.13
P-574	561	J-538	J-536	7.800	Existing 8" PVC	140.0	119	0.80	0.000	0.20
P-434	2,631	J-400	J-398	7.270	8" HDPE DR 13.5	140.0	243	1.88	0.002	4.85
P-406	864	J-374	J-372	7.270	8" HDPE DR 13.5	140.0	124	0.96	0.001	0.46
P-242	4,053	J-222	J-220	10.290	12" HDPE DR 11	140.0	504	1.94	0.001	5.32
P-182	813	J-162	J-160	9.750	12" HDPE DR 9	140.0	504	2.16	0.002	1.39
P-128	374	J-108	J-106	9.750	12" HDPE DR 9	140.0	504	2.16	0.002	0.64
P-126	228	J-106	J-104	9.750	12" HDPE DR 9	140.0	504	2.16	0.002	0.39
P-120	587	J-100	J-98	9.750	12" HDPE DR 9	140.0	504	2.16	0.002	1.00
P-68	735	J-50	J-48	10.290	12" HDPE DR 11	140.0	504	1.94	0.001	0.96
P-350	183	J-326	J-320	5.350	6" HDPE DR 11	140.0	305	4.35	0.011	2.06
P-378	3,178	J-348	J-340	5.584	6" HDPE DR 13.5	140.0	75	0.99	0.001	2.43
P-512	1,780	J-478	J-476	8.219	10" HDPE DR 9	140.0	244	1.47	0.001	1.82
P-508	2,212	J-474	J-472	8.679	10" HDPE DR 11	140.0	244	1.32	0.001	1.73
P-506	1,583	J-472	J-470	7.270	8" HDPE DR 13.5	140.0	244	1.88	0.002	2.94
P-462	3,020	J-428	J-426	7.270	8" HDPE DR 13.5	140.0	244	1.88	0.002	5.61
P-308	4,348	J-288	J-286	9.062	10" HDPE DR 13.5	140.0	504	2.51	0.002	10.60
P-298	1,492	J-278	J-276	9.062	10" HDPE DR 13.5	140.0	504	2.51	0.002	3.64
P-516	1,695	J-482	J-480	8.219	10" HDPE DR 9	140.0	244	1.47	0.001	1.73
P-562	510	Booster 1	J-526	8.679	10" HDPE DR 11	140.0	244	1.32	0.001	0.40
P-546	1,142	J-512	J-510	8.219	10" HDPE DR 9	140.0	244	1.47	0.001	1.17
P-42-1	1,818	J-34	J-29	3.440	4" HDPE DR 9	140.0	75	2.59	0.008	14.57

Hopi Regional Water System
FlexTable: Demand Table
Active Scenario: Inverted Y 2057

Label	Demand (Base) (gpm)	Pattern (Demand)	Demand Location
J-406	8.51	Navajo	Cultural Center
J-352	7.96	Navajo	Rt 17 Mishongnovi (Not Shown)
J-340	3.72	Navajo	Upper Sip/Mish Lower Level
J-344	0.37	Navajo	Upper Mishongnovi (Not Shown)
J-346	0.37	Navajo	Upper Sipaulovi (Not Shown)
J-348	2.53	Navajo	Peach Lane
J-34	215	Navajo	FMCV Distribution Side (Not Shown)
J-548	14.45	Navajo	Unserved Shungopavi
J-538	36.23	Navajo	Shungopavi
J-2	31.64	Navajo	Lower Sip/Mish

Hopi Regional Water System
FlexTable: Reservoir Table
Active Scenario: Inverted Y 2057

Current Time: 0.00 hours

Label	Elevation (ft)	Flow (Out net) (gpm)	Hydraulic Grade (ft)
TT Well #2	5,345.00	322	5,368.00
TT Well #3	5,298.00	305	5,336.00

Hopi Regional Water System
FlexTable: Pump Table
Active Scenario: Inverted Y 2057
Current Time: 3.25 hours

Label	Elevation (ft)	Pump Definition	Hydraulic Grade (Suction) (ft)	Hydraulic Grade (Discharge) (ft)	Flow (Total) (gpm)	Pump Head (ft)
Well 2	5,192.90	385S1000-12	5,345.00	6,199.75	310	854.75
Well 3	5,196.20	385S1000-12	5,298.00	6,192.92	283	894.92
Booster 1	6,140.00	CR45-4-2	6,161.85	6,500.70	245	338.85
Booster 2	6,325.00	CR20-2	6,389.76	6,487.42	120	97.66

Hopi Regional Water System
FlexTable: Tank Table
Active Scenario: Inverted Y 2057
Current Time: 0.25 hours

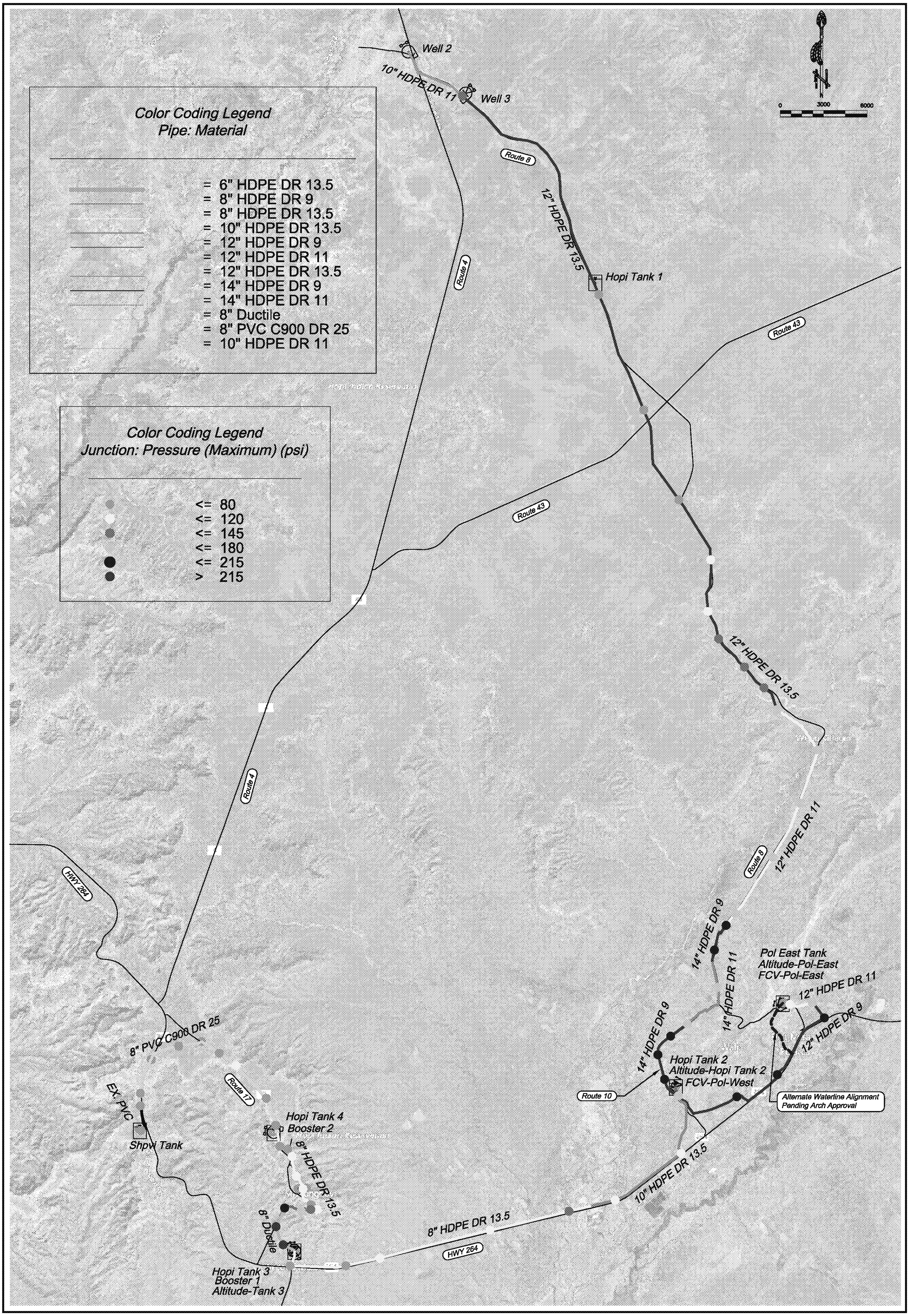
Label	Elevation (Base) (ft)	Elevation (Maximum) (ft)	Diameter (ft)	Flow (Out net) (gpm)	Percent Full (%)
Hopi Tank 1	6,142.00	6,166.00	48	121	86.4
Hopi Tank 2	6,345.00	6,400.00	17	-47	80

2019 Inverted Y 1000 hour Energy Cost Analysis

Year 2017	Label	Grundfos Pump Model	Time of Use (hours)	Utilization (%)	Volume Pumped (Total) (MG)	Water Power (Average) (kW)	Pump Efficiency (Average) (%)	Wire to Water Efficiency (Average) (%)	Wire Power (Average) (kW)	Energy Usage (Total) (kWh)	Energy Use Cost (Total) ($)	Energy Usage (Daily) (kWh)	Energy Use Cost (Daily) ($)	Cost per Unit Volume (Summary) ($/MG)	Annual Energy Cost
	Well 2	385S1000-12	271.5	27.1	5.08	49.9	72.6	63.9	78.5	21,299.60	2,129.96	511.2	51.12	420	
	Well 3	385S1000-12	271.5	27.1	4.62	47.6	70.6	62.1	77	20,907.50	2,090.75	501.8	50.18	452	
	Boost 1	CR45-4-2	233.4	23.3	3.35	15.6	76.4	67.3	23.1	5,386.90	538.69	129.30	12.93	161.00	
	Boost 2	CR20-2	205.2	20.5	1.5	2.2	70.2	63.2	3.4	691.80	69.18	16.60	1.66	46.00	
Total					**14.55**					**48,285.80**	**4,828.58**	**1,158.90**	**115.89**	**1,079.00**	**$42,299.85**

Year 2037	Label	Grundfos Pump Model	Time of Use (hours)	Utilization (%)	Volume Pumped (Total) (MG)	Water Power (Average) (kW)	Pump Efficiency (Average) (%)	Wire to Water Efficiency (Average) (%)	Wire Power (Average) (kW)	Energy Usage (Total) (kWh)	Energy Use Cost (Total) ($)	Energy Usage (Daily) (kWh)	Energy Use Cost (Daily) ($)	Cost per Unit Volume (Summary) ($/MG)	Annual
	Well 2	385S1000-12	388.4	38.8	7.23	50	72.7	63.9	78.1	30,313.60	3,031.36	727.5	72.75	419	
	Well 3	385S1000-12	388.4	38.8	6.58	47.6	70.6	62.1	76.5	29,726.10	2,972.61	713.4	71.34	452	
	Boost 1	CR45-4-2	326	32.6	4.73	15.6	76.4	67.2	23.3	7,584.60	758.46	182.00	18.20	160.00	
	Boost 2	CR20-2	297	29.7	2.15	2.2	71.3	64.2	3.4	1,007.70	100.77	24.20	2.42	47.00	
Total					**20.69**					**68,632.00**	**6,863.20**	**1,647.10**	**164.71**	**1,078.00**	**$60,119.15**

5/11/2019



Pressure
SHEET 01 OF 02

THE HOPI TRIBE
NAVAJO COUNTY, ARIZONA
Hopi Arsenic Mitigation Regional Water Project
Alternative J-Hook: Max Pressures in Water Model
PH 18-V31

DRAWN BY: JVV	DATE: 4-8-19	FILE NAME: J-HOOK
CHECKED BY: JPC/HR	DATE: ####	KA NUMBER: ####
APPROVED BY: ####	DATE: ####	PROJ ENG: ####

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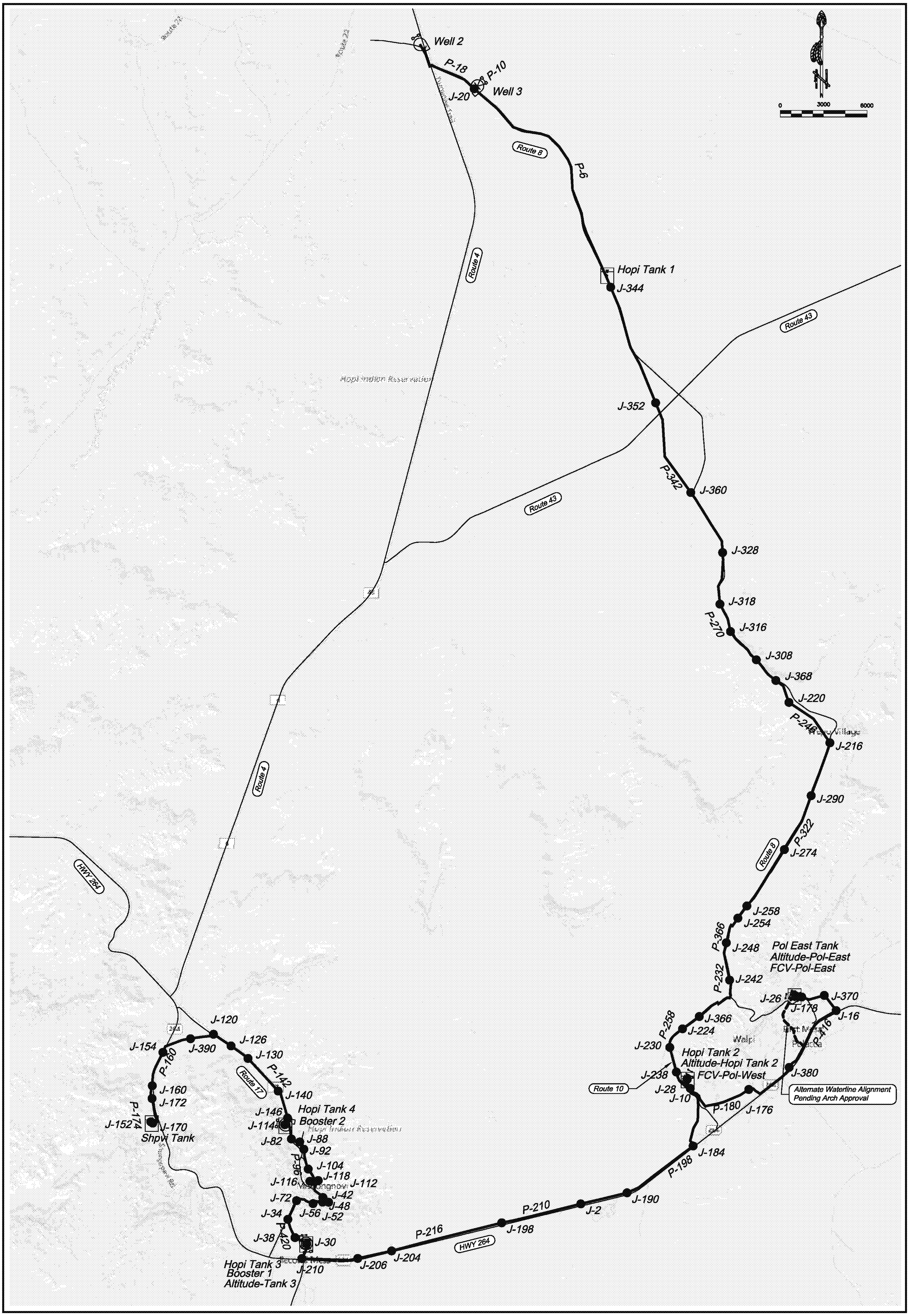
DATE	REVISIONS	INIT.



Labels	SHEET 01 OF 02

THE HOPI TRIBE
NAVAJO COUNTY, ARIZONA
Hopi Arsenic Mitigation Regional Water Project
Alternative J-Hook: Max Pressuree in Water Model
PH 18-V31

DRAWN BY: JVV	DATE: 4-8-19	FILE NAME: J-HOOK
CHECKED BY: JPC/BR	DATE: ####	EA NUMBER: ####
APPROVED BY: ####	DATE: ####	PROJ ENG: ####

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DATE	REVISIONS	INIT.

Hopi Regional Water System
FlexTable: Junction Table
Active Scenario: J-Hook 2057

Current Time: 0.25 hours

Label	Elevation (ft)	Pressure (Maximum) (psi)	Pressure (Minimum) (psi)
J-26	5,900.00	47	45
J-152	6,346.06	62	61
J-30	5,650.00	66	64
J-154	6,322.07	74	71
J-114	6,200.00	71	70
J-120	6,310.75	79	76
J-112	6,183.15	81	77
J-88	6,189.58	76	74
J-116	6,311.00	25	22
J-118	6,260.00	47	44
J-2	5,580.00	123	114
J-10	5,765.00	173	114
J-16	5,700.00	201	134
J-20	5,885.00	133	119
J-28	5,700.00	71	67
J-34	5,801.00	249	242
J-38	5,765.00	265	258
J-42	6,187.25	79	75
J-48	6,118.00	110	105
J-52	6,064.32	133	128
J-56	5,984.45	168	163
J-72	5,878.00	215	209
J-82	6,321.35	19	17
J-92	6,167.55	86	84
J-104	6,177.03	83	80
J-126	6,318.46	76	72
J-130	6,304.83	82	78
J-140	6,332.48	71	66
J-146	6,347.51	64	60
J-160	6,333.51	68	66
J-170	6,353.69	59	57
J-172	6,348.09	62	60
J-176	5,730.11	188	126
J-178	5,924.00	104	36
J-184	5,639.00	98	92
J-190	5,589.36	119	112
J-198	5,603.08	113	99
J-204	5,671.30	84	63
J-206	5,708.54	68	44
J-210	5,735.76	56	29
J-216	5,787.79	163	130
J-220	5,825.44	147	118
J-224	5,721.47	192	137

Hopi Regional Water System
FlexTable: Junction Table
Active Scenario: J-Hook 2057

Current Time: 0.25 hours

Label	Elevation (ft)	Pressure (Maximum) (psi)	Pressure (Minimum) (psi)
J-230	5,704.73	199	143
J-238	5,734.27	186	129
J-242	5,781.86	166	115
J-248	5,747.85	181	131
J-254	5,748.73	180	133
J-258	5,753.48	178	132
J-274	5,765.81	173	131
J-290	5,782.85	165	128
J-308	5,854.26	134	108
J-316	5,882.87	122	98
J-318	5,893.72	117	95
J-328	5,939.42	98	78
J-344	6,121.96	19	15
J-352	6,028.44	59	49
J-360	6,018.65	63	48
J-366	5,770.00	171	117
J-368	5,847.00	138	110
J-370	5,760.00	175	107
J-380	5,700.00	201	137
J-390	6,330.00	71	67

Hopi Regional Water System
FlexTable: Pipe Table
Active Scenario: J-Hook 2057
Current Time: 0.25 hours

Label	Length (3D) (ft)	Start Node	Stop Node	Diameter (in)	Material	C Factor	Flow (gpm)	Velocity (ft/s)	Headloss Gradient (ft/ft)	Headloss (ft)
P-6	17,037	J-20	Hopi Tank 1	10.750	12" HDPE DR 13.5	140.0	626	2.21	0.002	27.01
P-18	5,178	J-24	J-20	8.679	10" HDPE DR 11	140.0	322	1.75	0.001	6.80
P-96	85	J-96	J-98	7.270	8" HDPE DR 13.5	140.0	175	1.35	0.001	0.08
P-142	869	J-134	J-132	8.280	8" PVC C900 DR 25	140.0	134	0.80	0.000	0.28
P-160	732	J-156	J-158	8.280	8" PVC C900 DR 25	140.0	131	0.78	0.000	0.23
P-174	656	J-172	J-164	7.800	PVC	140.0	131	0.88	0.000	0.27
P-180	4,937	J-10	J-176	9.750	12" HDPE DR 9	140.0	440	1.89	0.001	6.57
P-198	2,014	J-186	J-188	9.062	10" HDPE DR 13.5	140.0	262	1.30	0.001	1.46
P-210	2,194	J-196	J-198	7.270	8" HDPE DR 13.5	140.0	262	2.02	0.002	4.65
P-216	2,626	J-202	J-204	7.270	8" HDPE DR 13.5	140.0	262	2.02	0.002	5.56
P-232	952	J-242	J-218	11.300	14" HDPE DR 11	140.0	690	2.21	0.001	1.42
P-246	4,049	J-220	J-216	10.290	12" HDPE DR 11	140.0	690	2.66	0.002	9.52
P-258	799	J-228	J-230	10.700	14" HDPE DR 9	140.0	690	2.46	0.002	1.55
P-270	2,046	J-318	J-316	10.750	12" HDPE DR 13.5	140.0	690	2.44	0.002	3.89
P-322	548	J-278	J-276	10.290	12" HDPE DR 11	140.0	690	2.66	0.002	1.29
P-342	2,318	J-356	J-358	10.750	12" HDPE DR 13.5	140.0	690	2.44	0.002	4.41
P-416	3,880	J-382	J-16	9.750	12" HDPE DR 9	140.0	440	1.89	0.001	5.16
P-420	431	J-384	J-34	8.430	8" Ductile	110.0	176	1.01	0.001	0.33

Hopi Regional Water System
FlexTable: Demand Table
Active Scenario: J-Hook 2057
Current Time: 0.25 hours

Label	Demand (Base) (gpm)	Pattern (Demand)	Demand Location
J-30	31.64	Navajo	Lower Sip/Mish
J-112	3.72	Navajo	Upper Second Mesa
J-118	0.37	Navajo	Second Mesa Yard Hydrants
J-116	0.37	Navajo	Second Mesa Yard Hydrants
J-88	2.53	Navajo	Future Peach Lane
J-114	7.96	Navajo	Route 17 Upper
J-26	215	Navajo	FMCV
J-154	15.5	Navajo	Route 264 Shungopavi
J-120	7.5	Navajo	Cultural Center
J-152	36.2	Navajo	Shungopavi

Hopi Regional Water System
FlexTable: Reservoir Table
Active Scenario: J-Hook 2057
Current Time: 0.25 hours

Label	Elevation (ft)	Flow (Out net) (gpm)	Hydraulic Grade (ft)
R-3	5,298.00	281	5,298.00
R-2	5,345.00	310	5,345.00

Hopi Regional Water System
FlexTable: Pump Table
Active Scenario: J-Hook 2057
Current Time: 0.25 hours

Label	Elevation (ft)	Pump Definition	Hydraulic Grade (Suction) (ft)	Hydraulic Grade (Discharge) (ft)	Flow (Total) (gpm)	Pump Head (ft)
Well 2	5,212.90	385S1000-12	5,345.00	6,200.12	310	855.12
Well 3	5,196.20	385S1000-12	5,298.00	6,195.87	281	897.87
Booster 1	5,780.00	CR32-9-2	5,803.25	6,376.33	176	573.08
Booster 2	6,345.00	CR20-3	6,363.10	6,495.19	134	132.09

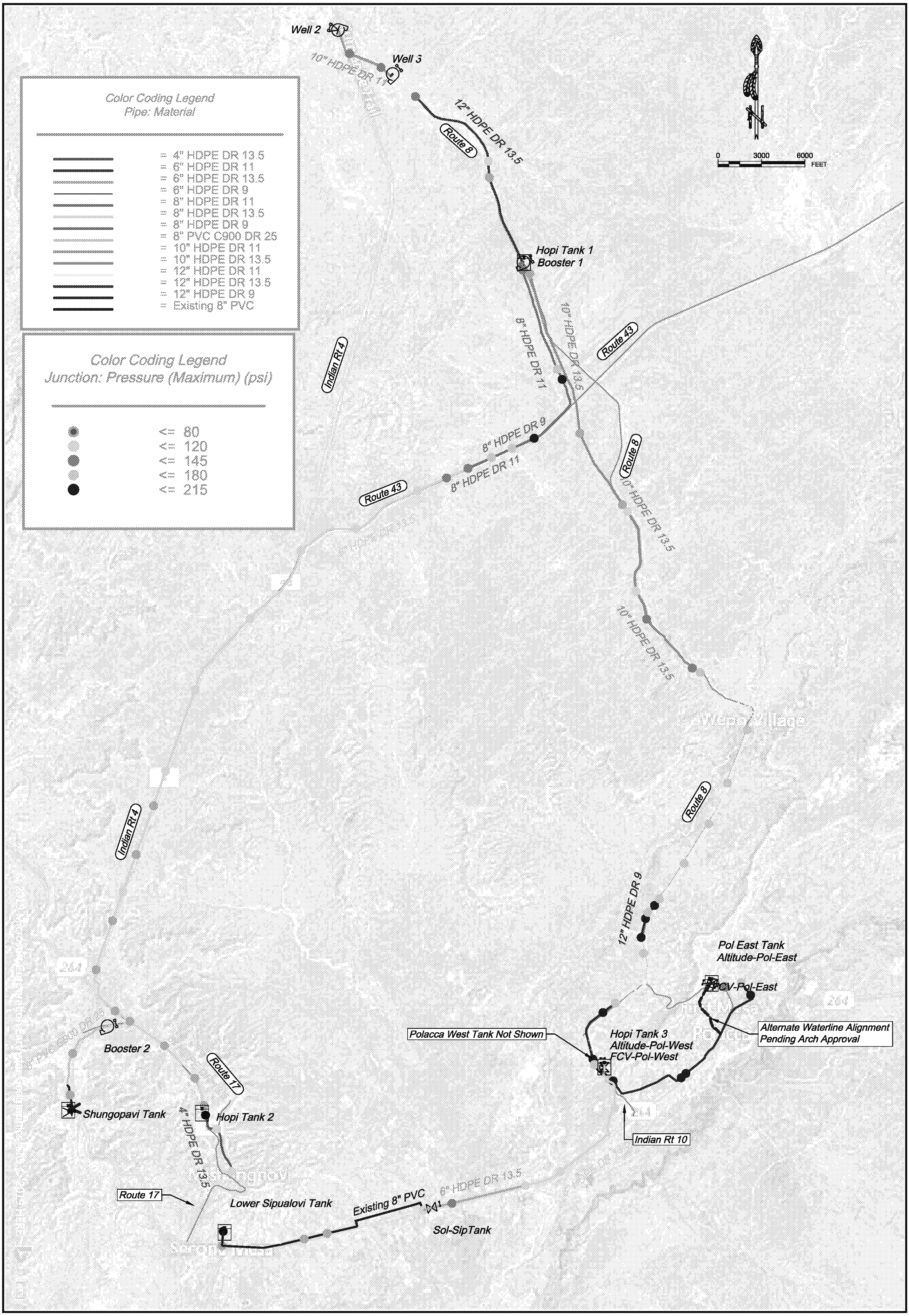
Hopi Regional Water System
FlexTable: Tank Table
Active Scenario: J-Hook 2057
Current Time: 0.25 hours

Label	Elevation (Base) (ft)	Elevation (Maximum) (ft)	Diameter (ft)	Flow (Out net) (gpm)	Percent Full (%)
Hopi Tank 2	5,823.00	5,865.00	28	12	90.1
Hopi Tank 3	5,780.00	5,804.00	28	-83	96.8
Hopi Tank 1	6,142.00	6,166.00	45	65	86.6
Hopi Tank 4	6,345.00	6,365.00	31	-41	89.5

2019 J-Hook 1000 hour Energy Analysis

Year 2017	Label	Nominal HP	Grundfos Pump Model	Time of Use (hours)	Utilization (%)	Volume Pumped (Total) (MG)	Water Power (Average) (kW)	Pump Efficiency (Average) (%)	Wire to Water Efficiency (Average) (%)	Wire Power (Average) (kW)	Energy Usage (Total) (kWh)	Energy Use Cost (Total) ($)	Energy Usage (Daily) (kWh)	Energy Use Cost (Daily) ($)	Cost per Unit Volume (Summary) ($/MG)	Annual Energy Cost
	Well 2	100	385S1000-12	257.7	25.8	4.42	47.6	70.6	62.1	77.8	20,041.60	2,004.16	481	48.1	453	
	Well 3	100	385S1000-12	257.7	25.8	4.97	50.8	72.2	63.6	81.8	21,072.30	2,107.23	505.7	50.57	424	
	Boost 1	20	CR45-3-2	211.3	21.1	2.22	19	72.9	72.9	26	5,493.60	549.36	131.8	13.18	247	
	Boost 2	5	CR20-2	215	21.5	1.71	3.3	66.2	58.3	5.5	1,192.40	119.24	28.6	2.86	70	
Total						**13.32**					**47,799.90**	**4,779.99**	**1,147.10**	**114.71**	**1,194.00**	**$ 41,869.15**

Year 2037	Label		Grundfos Pump Model	Time of Use (hours)	Utilization (%)	Volume Pumped (Total) (MG)	Water Power (Average) (kW)	Pump Efficiency (Average) (%)	Wire to Water Efficiency (Average) (%)	Wire Power (Average) (kW)	Energy Usage (Total) (kWh)	Energy Use Cost (Total) ($)	Energy Usage (Daily) (kWh)	Energy Use Cost (Daily) ($)	Cost per Unit Volume (Summary) ($/MG)	Annual
	Well 2	100	385S1000-12	372.2	37.2	7.1	50.7	72.3	63.6	80.9	30,100.20	3,010.02	722.4	72.24	424	
	Well 3	100	385S1000-12	372.2	37.2	6.3	47.6	70.5	62.1	76.7	28,543.80	2,854.38	685.1	68.51	453	
	Boost 1	20	CR45-3-2	295.1	29.5	3.14	18.9	72.9	72.9	26.3	7,770.80	777.08	186.5	18.65	247	
	Boost 2	5	CR20-2	309.3	30.9	2.46	3.3	66.8	58.8	5.6	1,734.50	173.45	41.6	4.16	70	
Total						**19**					**68,149.30**	**6,814.93**	**1,635.60**	**163.56**	**1,194.00**	**$ 59,699.40**



SHEET 02 OF 06

YJ Press

THE HOPI TRIBE
NAVAJO COUNTY, ARIZONA
Hopi Arsenic Mitigation Regional Water Project
Alternative Hybrid YJ: Max Pressure in Water Model
PH 18-V31

DRAWN BY: JPC	DATE: 6-3-19	FILE NAME: INVERTED Y
CHECKED BY: JVV/RH	DATE:	PA NUMBER:
APPROVED BY:	DATE:	PROJ ENG:

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DATE	REVISIONS	INIT.

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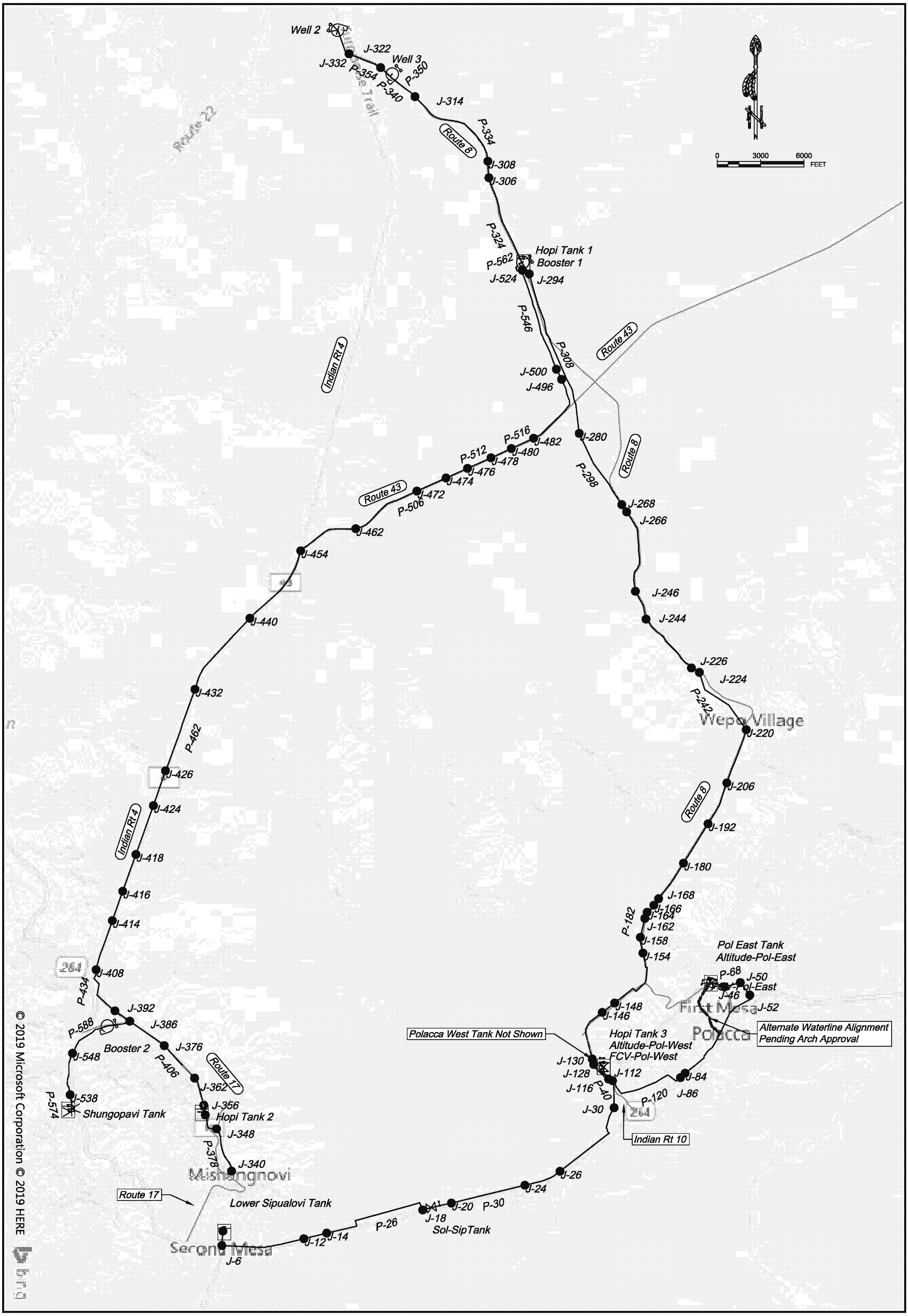

SHEET 01 OF 6

YJ Model ID

THE HOPI TRIBE

NAVAJO COUNTY, ARIZONA

Hopi Arsenic Mitigation Regional Water Project

Alternative Hybrid YJ: IDs in Water Model

PH 18-V31

DRAWN BY: JPC	DATE: 4-4-19	FILE NAME: INVERTED Y	
CHECKED BY: JVV/BR	DATE:	DA NUMBER:	
APPROVED BY:	DATE:	PROJ ENG:	

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(928) 737-6000

DATE	REVISIONS	INIT.

Hopi Regional Water System
FlexTable: Junction Table
Active Scenario: Hybrid 2057
Current Time: 0.25 hours

Label	Elevation (ft)	Pressure (Maximum) (psi)	Pressure (Minimum) (psi)
J-340	6,185.00	93	87
J-348	6,190.00	90	85
J-306	6,000.00	76	70
J-414	6,235.00	76	62
J-224	5,829.00	145	105
J-154	5,777.00	168	112
J-148	5,770.00	171	112
J-226	5,847.00	138	98
J-332	5,893.84	131	116
J-314	5,905.00	123	111
J-408	6,294.95	49	36
J-308	5,981.00	85	78
J-322	5,880.00	136	122
J-548	6,329.30	70	67
J-538	6,327.73	70	68
J-392	6,313.48	40	28
J-386	6,310.75	40	29
J-376	6,304.83	42	34
J-362	6,332.48	29	24
J-356	6,347.51	22	17
J-158	5,747.60	181	126
J-162	5,740.34	184	130
J-164	5,749.09	180	126
J-166	5,748.73	180	127
J-168	5,751.47	179	127
J-180	5,770.91	171	120
J-192	5,773.42	169	121
J-206	5,782.85	165	119
J-220	5,787.79	163	119
J-244	5,882.87	122	88
J-246	5,893.72	117	86
J-266	5,977.03	81	57
J-268	5,998.56	72	48
J-50	5,760.10	175	105
J-46	5,875.43	125	55
J-146	5,730.11	188	128
J-130	5,734.27	186	123
J-128	5,756.54	177	113
J-116	5,750.63	179	115
J-112	5,733.56	187	122
J-84	5,688.85	206	139
J-86	5,686.96	207	140
J-52	5,715.15	195	125

Hopi Regional Water System
FlexTable: Junction Table
Active Scenario: Hybrid 2057

Current Time: 0.25 hours

Label	Elevation (ft)	Pressure (Maximum) (psi)	Pressure (Minimum) (psi)
J-480	6,033.85	178	149
J-478	6,052.72	169	140
J-476	6,110.23	143	116
J-474	6,151.48	125	98
J-472	6,174.29	114	88
J-462	6,218.57	94	69
J-454	6,191.71	104	80
J-440	6,212.33	93	71
J-432	6,195.92	98	78
J-426	6,221.10	85	68
J-424	6,255.18	70	53
J-418	6,269.55	62	47
J-416	6,225.43	81	66
J-294	6,121.96	19	16
J-280	6,023.32	61	45
J-482	6,018.43	185	155
J-500	6,040.84	179	146
J-496	6,033.78	181	149
J-524	6,125.52	145	109
J-30	5,665.52	84	78
J-26	5,604.90	111	101
J-24	5,593.18	118	105
J-20	5,594.09	125	96
J-18	5,601.92	92	82
J-14	5,649.24	69	64
J-12	5,677.00	56	52
J-6	5,738.58	28	25

Hopi Regional Water System
FlexTable: Pipe Table
Active Scenario: Hybrid 2057
Current Time: 0.25 hours

Label	Length (3D) (ft)	Start Node	Stop Node	Diameter (in)	Material	C Factor	Flow (gpm)	Velocity (ft/s)	Headloss Gradient (ft/ft)	Headloss (ft)
P-340	2,215	J-316	J-314	10.290	12" HDPE DR 11	140.0	627	2.42	0.002	4.26
P-334	2,101	J-310	J-308	10.750	12" HDPE DR 13.5	140.0	627	2.21	0.002	3.27
P-324	3,195	J-300	J-298	10.750	12" HDPE DR 13.5	140.0	627	2.21	0.002	4.97
P-354	885	J-328	J-324	8.679	10" HDPE DR 11	140.0	322	1.74	0.001	1.16
P-588	1,041	J-552	J-550	8.280	8" PVC C900 DR 25	140.0	0	0.00	0.000	0.00
P-574	561	J-538	J-536	7.800	Existing 8" PVC	140.0	-18	0.12	0.000	0.01
P-434	2,631	J-400	J-398	7.270	8" HDPE DR 13.5	140.0	135	1.05	0.001	1.64
P-406	864	J-374	J-372	7.270	8" HDPE DR 13.5	140.0	135	1.05	0.001	0.54
P-242	4,053	J-222	J-220	10.290	12" HDPE DR 11	140.0	541	2.09	0.001	6.07
P-182	813	J-162	J-160	9.750	12" HDPE DR 9	140.0	541	2.33	0.002	1.58
P-128	374	J-108	J-106	9.750	12" HDPE DR 9	140.0	341	1.47	0.001	0.31
P-126	228	J-106	J-104	9.750	12" HDPE DR 9	140.0	341	1.47	0.001	0.19
P-120	587	J-100	J-98	9.750	12" HDPE DR 9	140.0	341	1.47	0.001	0.49
P-68	735	J-50	J-48	10.290	12" HDPE DR 11	140.0	341	1.32	0.001	0.47
P-350	183	J-326	J-320	5.350	6" HDPE DR 11	140.0	305	4.35	0.011	2.06
P-378	3,178	J-348	J-340	3.794	4" HDPE DR 13.5	140.0	11	0.32	0.000	0.46
P-512	1,780	J-478	J-476	6.963	8" HDPE DR 11	140.0	157	1.32	0.001	1.80
P-506	1,583	J-472	J-470	7.270	8" HDPE DR 13.5	140.0	157	1.21	0.001	1.30
P-462	3,020	J-428	J-426	7.270	8" HDPE DR 13.5	140.0	157	1.21	0.001	2.47
P-308	4,348	J-288	J-286	9.062	10" HDPE DR 13.5	140.0	541	2.69	0.003	12.10
P-298	1,492	J-278	J-276	9.062	10" HDPE DR 13.5	140.0	541	2.69	0.003	4.15
P-516	1,695	J-482	J-480	6.590	8" HDPE DR 9	140.0	157	1.47	0.001	2.24
P-562	510	Booster 1	J-526	6.963	8" HDPE DR 11	140.0	157	1.32	0.001	0.51
P-546	1,142	J-512	J-510	6.963	8" HDPE DR 11	140.0	157	1.32	0.001	1.15
P-26	5,562	J-16	J-18	7.800	Existing 8" PVC	140.0	-180	1.21	0.001	4.18
P-30	2,559	J-20	J-22	5.584	6" HDPE DR 13.5	140.0	-180	2.36	0.004	9.78
P-40	3,181	J-30	J-32	7.270	8" HDPE DR 13.5	140.0	-180	1.39	0.001	3.36

Hopi Regional Water System
FlexTable: Demand Table
Active Scenario: Hybrid 2057

Label	Demand (Base) (gpm)	Pattern (Demand)	Demand Location
J-406	8.51	Navajo	Cultural Center
J-352	7.96	Navajo	Rt 17 Mishongnovi (Not Shown)
J-340	3.72	Navajo	Upper Sip/Mish Lower Level
J-344	0.37	Navajo	Upper Sipaulovi (Not Shown)
J-346	0.37	Navajo	Upper Mishongnovi (Not Shown)
J-348	2.53	Navajo	Peach Lane
J-34	215	Navajo	FMCV Distribution Side (Not Shown)
J-548	14.45	Navajo	Unserved Shungopavi
J-538	36.23	Navajo	Shungopavi
J-6	31.64	Navajo	Lower Sipaulovi

Hopi Regional Water System
FlexTable: Reservoir Table
Active Scenario: Hybrid 2057

Current Time: 0.00 hours

Label	Elevation (ft)	Flow (Out net) (gpm)	Hydraulic Grade (ft)
TT Well #2	5,345.00	309	5,345.00
TT Well #3	5,298.00	281	5,298.00

Hopi Regional Water System
FlexTable: Pump Table
Active Scenario: Hybrid 2057
Current Time: 2.25 hours

Label	Elevation (ft)	Pump Definition	Hydraulic Grade (Suction) (ft)	Hydraulic Grade (Discharge) (ft)	Flow (Total) (gpm)	Pump Head (ft)
Well 2	5,192.90	385S1000-12	5,345.00	6,200.46	309	855.46
Well 3	5,196.20	385S1000-12	5,298.00	6,194.91	281	896.91
Booster 1	6,140.00	CR45-3-2	6,161.92	6,454.18	158	292.26
Booster 2	6,325.00	CR20-2	6,389.50	6,486.88	122	97.38

Hopi Regional Water System
FlexTable: Tank Table
Active Scenario: Hybrid 2057
Current Time: 0.25 hours

Label	Elevation (Base) (ft)	Elevation (Maximum) (ft)	Diameter (ft)	Flow (Out net) (gpm)	Percent Full (%)
Hopi Tank 1	6,142.00	6,166.00	48	71	86.6
Hopi Tank 2	6,345.00	6,400.00	17	-98	77.1
Hopi Tank 3	5,823.00	5,861.00	22	-20	68.7

2019 JY Hybrid 1000 hour Energy Analysis

Year 2017	Label	Nominal HP	Grundfos Pump Model	Time of Use (hours)	Utilization (%)	Volume Pumped (Total) (MG)	Water Power (Average) (kW)	Pump Efficiency (Average) (%)	Wire to Water Efficiency (Average) (%)	Wire Power (Average) (kW)	Energy Usage (Total) (kWh)	Energy Use Cost (Total) ($)	Energy Usage (Daily) (kWh)	Energy Use Cost (Daily) ($)	Cost per Unit Volume (Summary) ($/MG)	Annual Energy Cost
	Well 2	100	385S1000-12	269.5	26.9	5.03	49.8	72.6	63.9	78.4	21,126.70	2,112.67	507	50.7	420	
	Well 3	100	385S1000-12	269.5	26.9	4.58	47.6	70.6	62.1	77	20,761.00	2,076.10	498.3	49.83	453	
	Boost 1	20	CR45-3-2	245.5	24.6	2.29	8.5	71.1	64	13.4	3,294.10	329.41	79.10	7.91	144.00	
	Boost 2	5	CR20-2	209.9	21	1.5	2.2	71.7	64.5	3.2	673.70	67.37	16.20	1.62	45.00	
Total						**13.4**					**45,855.50**	**4,585.55**	**1,100.60**	**110.06**	**1,062.00**	**$ 40,171.90**

Year 2037	Label		Grundfos Pump Model	Time of Use (hours)	Utilization (%)	Volume Pumped (Total) (MG)	Water Power (Average) (kW)	Pump Efficiency (Average) (%)	Wire to Water Efficiency (Average) (%)	Wire Power (Average) (kW)	Energy Usage (Total) (kWh)	Energy Use Cost (Total) ($)	Energy Usage (Daily) (kWh)	Energy Use Cost (Daily) ($)	Cost per Unit Volume (Summary) ($/MG)	Annual
	Well 2	100	385S1000-12	384.8	38.5	7.13	49.8	72.6	63.9	77.8	29,936.60	2,993.66	718.5	71.85	420	
	Well 3	100	385S1000-12	384.8	38.5	6.5	47.6	70.6	62.1	76.5	29,421.90	2,942.19	706.1	70.61	453	
	Boost 1	20	CR45-3-2	344.4	34.4	3.21	8.5	71.1	64	13.4	4,623.40	462.34	111.00	11.10	144.00	
	Boost 2	5	CR20-2	297.8	29.8	2.15	2.2	71.9	64.7	3.4	1,009.20	100.92	24.20	2.42	47.00	
Total						**18.99**					**64,991.10**	**6,499.11**	**1,559.80**	**155.98**	**1,064.00**	**$ 56,932.70**